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EARLY DEFLORATION AS A METHOD OF INCREASING COTTON YIELDS, AND THE RELATION OF FRUITFULNESS TO FIBER AND BOLL CHARACTERS [1]

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INTRODUCTION

A study of the growth reactions of the cotton plant in Arizona during the seasons of 1926 and 1927 indicated that it might be possible, at least under some conditions, materially to increase cotton yields by artificially delaying for several weeks the normal initiation of boll setting. The premises for this view were briefly as follows: Experiments had shown that an increased vegetative growth, an increased rate of floral-bud formation, and a decreased shedding rate followed when all previously set bolls were removed from cotton plants. These results,[3] which were generally confirmed by Murneek's results with the tomato,[4] indicated in addition that plants so treated carried a heavier boll load, in proportion to their size, soon after defruiting than did untreated control plants. This latter observation, which can not be fully explained, is considered as having had an important bearing on the outcome of the experiments herein reported. The effect of defruiting on the rate at which new bolls are set is shown graphically in Figure 1. During the 36-day interval between the first and second defruiting the 25 control plants increased the number of bolls carried at an average rate of 3.5 bolls per day; whereas the defruited plants increased the number of bolls carried at the rate of 10.7 bolls per day. Other experiments showed, also, that a more extensive root system was developed by plants grown without bolls, or with a limited number of bolls during the early part of the season, than by normally fruited plants. The nutritional dominance of bolls over the vegetative growth of the cotton plant had frequently been observed to inhibit boll setting and terminal bud and branch development. A reduction in growth rates following the initiation of flowering and boll setting was a common observation. On the basis of general physiological grounds it was recognized that the number of bolls that can be developed by a cotton plant is not only relative to the favorableness of environmental conditions, among other factors, but is also directly related to the leaf area of the plant. In view of these facts and indicated relationships, it seemed logical to assume that an increased yield would result if the first bolls set by cotton plants were sacrificed in favor of a larger plant with a greater initial photosynthetic capacity.

The extent to which cotton yields could be increased by this method were considered as being dependent upon two primary but

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[3] EATON, F. M. DEFRUITING AS AN AID IN COTTON BREEDING. Jour. Heredity 18: 456-460. 1927.

[4] MURNEEK, A. E. EFFECT OF CORRELATION BETWEEN VEGETATIVE AND REPRODUCTIVE FUNCTIONS IN THE TOMATO. Plant Physiol. 1: 3-56, illus. 1926.

undetermined factors: (1) The length of time that the initiation of boll setting should be delayed in order to gain the most advantageous effect, and (2) the extent to which boll development is dominant over vegetative growth in different varieties of cotton. The conditions that determine such dominance are imperfectly understood, but it is known that different varieties may behave quite differently

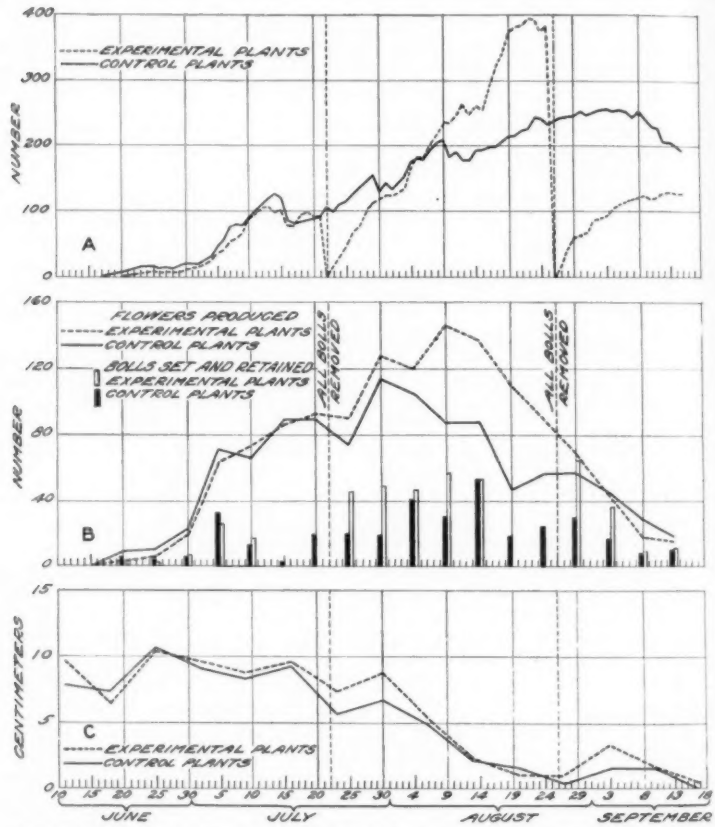

FIGURE 1.—Effect of defruiting, i. e., removing all bolls, on (A) the daily number of developing bolls carried by 25 Acala cotton plants, (B) the number of flowers produced and the number of bolls set and retained from these flowers on 25 plants, and (C) the weekly elongation rates. In each graph the defruited (experimental) plants are compared with untreated (control) plants

in different localities and to a lesser extent in different seasons. Presumably, a determinate cotton variety, i. e., one that tends to set a heavy crop of early bolls, should give the most outstanding response to this treatment; whereas a variety inclined to make a rank growth early in the season might benefit little or not at all. The Acala strain used in experiments herein reported has proved to be less determinate in its growth and better suited to Arizona conditions than other strains with which it has been compared.

The experimental plans for testing the possibility of increasing yields by delayed boll setting were so arranged that data would be supplied on the effects of the treatments on boll characteristics and on the quality of fiber produced. The delayed initiation of boll setting was accomplished by removing all flowers from experimental plants during the early part of the flowering period. To augment the data on the effect of plant load on boll and fiber characters, a second treatment was included to make possible observations on the behavior of sparsely fruited plants. This latter purpose was accomplished, with other plants, by limiting boll setting to the first node of any fruiting branch.

The present paper, therefore, is a report of an investigation on the effect upon yields of delayed boll setting and on the effect upon the bolls and fiber of treatments resulting in plants that were either more heavily or more lightly fruited than untreated control plants.[5]

Florists and horticulturists have recognized for many centuries that when only a few of the flowers or fruits on a plant are left to develop, a superior product may be expected. The characters of the bolls and fiber of a particular variety of cotton are relatively stable, and the effect of the difference in the number of bolls borne by otherwise similar cotton plants upon boll size and the character of the ginned cotton has not been previously determined. It was desirable that this important relation should be worked out; and in connection with the proposed method for increasing yields it seemed especially desirable, if not necessary, that the effect of plant load on fiber character should be determined.

The difference in nutritional relationship between bolls on sparsely and on heavily fruited plants must, in a large measure, be comparable to the differences which are brought about by changes from favorable to unfavorable environmental conditions, since in either case the competition among the growing bolls for available nutrients is of primary importance. Therefore, to the problem of the effect of adverse climatic and soil conditions upon boll and fiber characters a partial solution is suggested by the data herein presented.

The greater number of the observations preceding the present experimental investigation had been made on the Acala upland variety. The Pima Egyptian cotton is very different from upland cotton, not only in its morphology but also in many of its physiological characteristics and growth reactions. For these reasons uncertainty was felt as to what effect early defloration would have on Pima yields. The same treatment was applied to each variety, and, as will be noted later, the early-deflorated Pima plants did not set a heavier crop until late in the season. The Pima plant produces a smaller boll than the Acala and is much less determinate in its growth. Under field conditions an early setting of bolls on Pima plants does not retard growth and cause flowers to shed to the extent that it does in Acala.

EXPERIMENTAL METHODS

The experimental plants, both Acala upland and Pima Egyptian, were grown in plot D–1–17, United States Field Station, Sacaton, Ariz., during the season of 1928. The plot was 200 feet long and was

[5] Special acknowledgment is due Carl A. Moosberg for the immediate care of the experiments, for the greater portion of the measurements, and for aid in the tabulation of the results.

planted with four rows of Acala and three rows of Pima. The rows were 42 inches apart, and the plants were thinned to 15 inches apart in each row.

From each branch of 75 plants of each variety all flowers or floral buds of large size appearing at fruiting-branch nodes beyond the first were systematically removed throughout the flowering season. In tables and discussions these plants will be referred to as the 1-boll-per-branch plants. A number of the first nodes of the fruiting branches, particularly in the Acala variety, failed to develop a boll; as no other flower had been left to develop, such branches remained barren.

In an adjacent row, in both the Acala and Pima sections, all flowers or floral buds of large size were systematically removed from 25 plants until July 25, after which date the flowering and boll setting of the plants were not interfered with. These plants, each third plant of the row, will be referred to as the early-deflorated plants. The 50 plants intervening in pairs between the consecutive early-deflorated plants were reserved as control plants.

In this experiment the flowering season was divided into three periods: (1) July 1 to August 4, (2) August 5 to August 22, and (3) August 23 to September 15. On August 4 all flowers and previously set bolls on all the plants were tagged with blue tags. From August 5 to August 22, inclusive, an 18-day period, all flowers were marked with dated white tags as they appeared, and flowers that appeared subsequently remained untagged. If bolls from the middle or white-tag period developed, the date of opening was also recorded on the tag. As soon as any boll of this experiment opened it was inclosed in a paper bag to protect the seed cotton and prevent its loss. All vegetative branches were removed from the plants as they appeared, thus leaving only the main axes and fruiting branches.

A considerable portion of the information reported herein was derived from measurements made on 100-boll samples. These samples were selected at random after each crop was gathered but before the bolls were removed from their individual paper bags.

Very few flowers appeared after the middle of September on any of the experimental plants. Flowers set at a later date do not contribute materially to the yield of cotton in Arizona. In this experiment the last cotton was picked on November 13, following frosts which occurred during the second week in November. In a supplementary experiment, which will be described later in this paper, the last picking was made on January 3; but the bulk of the cotton from that experiment was picked on October 10. The vegetative branches were not removed from the plants in the supplementary experiment.

EXPERIMENTAL RESULTS

NUMBER OF MATURE BOLLS AND WEIGHT OF FIBER AND SEED

In Table 1 the effects of the various treatments upon the two varieties are given in terms of the number of bolls matured and the quantity of fiber and seed produced per plant from the flowers appearing during the three periods into which the experiment was divided. The ratios of weight of fiber to weight of seed are also given.

By the end of the first period the Acala 1-boll-per-branch plants had set approximately half as many bolls as the control plants,

whereas the early-deflorated plants had set approximately 10 per cent more bolls than the control plants.

TABLE 1.—*Mean number of mature bolls and mean weight of fiber and seed per plant in Acala and Pima cotton, from flowers of each period of season (July 1 to September 15, 1928) for each of three treatments*

Period and treatment	Acala				Pima			
	Mean bolls per plant	Mean weight of fiber	Mean weight of seed	Ratio of fiber weight to weight of seed	Mean bolls per plant	Mean weight of fiber	Mean weight of seed	Ratio of fiber weight to weight of seed
First period (from flowers of July 1 to August 4):	*Number*	*Grams*	*Grams*		*Number*	*Grams*	*Grams*	
1 boll per branch	7.33	18.5	35.5	0.520	11.45	8.9	26.8	0.332
Control	14.14	33.8	62.9	.538	28.02	24.3	58.2	.418
Early deflorated	15.68	36.0	66.2	.544	13.96	13.1	32.6	.402
Second period (from flowers of August 5 to 22):								
1 boll per branch	2.16	5.3	10.6	.500	3.17	3.2	8.6	.372
Control	2.16	4.8	9.5	.505	10.70	8.7	22.0	.395
Early deflorated	4.40	9.6	16.8	.571	21.08	19.9	48.7	.409
Third period (from flowers of August 23 to September 15):								
1 boll per branch	1.20	2.8	5.7	.492	1.95	3.1	7.5	.414
Control	.50	1.0	2.2	.455	3.64	3.9	9.7	.402
Early deflorated	0	0	0		14.88	13.2	28.1	.470
Total or average for season:								
1 boll per branch	[a] 10.7	26.6	51.8	.514	16.6	15.2	42.9	.354
Control	[a] 16.8	39.6	74.6	.531	42.4	36.9	89.9	.410
Early deflorated	[a] 20.1	45.6	83.0	.550	49.9	46.2	109.4	.422

[a] All values in this table, except the number of bolls per plant in Acala, were derived from the gross yields of the respective treatments and periods. The number of bolls on each of the Acala plants was counted separately, and the probable errors for the season are as follows: One boll per branch, 10.70±0.23 control, 16.8±0.36; deflorated to July 26, 20.1±0.50. The difference between the control and early-deflorated Acala is 3.3±0.62.

Boll setting during the second period was comparatively light in Acala for each of the three treatments, but the early-deflorated plants set more bolls than either the control plants or the 1-boll-per-branch plants. By the end of this period the early-deflorated plants had set 23 per cent more bolls than the control plants.

Early defloration (Table 1) resulted in a larger crop in both the Acala upland and Pima Egyptian varieties, irrespective of whether the difference is measured in terms of the number of mature bolls or the weight of fiber. The differences in the ratios of fiber to seed indicate that early defloration increased the weight of fiber per plant relatively more than the weight of seed.

GROWTH OF PLANTS AND NUMBER OF FIRST-NODE BOLLS RETAINED

Detailed measurements were made on the Acala upland plants at the end of the season, but only the height of the Pima plants was recorded. Table 2 shows that the plants of both varieties attained greater height when boll setting was limited to the first node of each branch. Early defloration stimulated the vegetative growth of both the Acala and the Pima plants during the first part of the flowering period; and the Pima plants were still growing more rapidly than the controls as late as September.

TABLE 2.—*Mean height of Acala and Pima plants at end of season (November 13, 1928), and mean number of fruiting branches and first-node bolls per plant on Acala*

ACALA

Treatment	Mean height	Mean first-node bolls on fruiting branches	Mean fruiting branches
	Inches	*Number*	*Number*
1 boll per branch	47.9	10.7	24.5
Control	41.7	5.5	22.6
Early deflorated	45.5	[a] 2.6	24.1

PIMA

1 boll per branch	62.8		
Control	50.2		
Early deflorated	57.8		

[a] Many of the flowers at the first nodes of these plants were removed during the early-defloration period.

The Acala 1-boll-per-branch plants produced approximately twice as many bolls on the first nodes of the fruiting branches as did the control plants. The number of bolls on the first nodes of the fruiting branches of the early-deflorated plants was low, since many of the flowers at these positions had been removed during the early-defloration period.

MEAN WEIGHT OF BOLLS AND BURS, SEED COTTON, FIBER, AND SEED PER BOLL

In the upland variety (Acala) the comparisons of the boll characters from flowers appearing during the second period of the experiment were looked upon as furnishing the best data for the determination of the influence of the number of bolls per plant on boll characters. Bolls from the second-period flowers in the different treatments developed under the greatest extremes with respect to the total load on the plants and therefore with respect to competition between bolls. Similar relations existed between the bolls of the different treatments set during the first period, but the bolls of the early-deflorated plants were all set during the last 10 days of that 35-day period, and a seasonal factor was therefore introduced. In considering the results of the Acala upland comparisons it should be borne in mind that the bulk of the crop was from first-period flowers. The Acala early-deflorated plants produced no bolls from third-period flowers, whereas the similarly treated Pima plants produced almost a third of their crop from these flowers.

The total load on the early deflorated Pima plants (Table 1) did not equal the load on the control plants until the last period, and as a result, in terms of plant load, the early-deflorated Pima plants occupy a position between the 1-boll-per-branch and the control plants. Early deflorations of the Pima plants greatly stimulated vegetative development, and, relative to plant size or leaf area, the boll load on the early-deflorated Pima plants was probably always less than that on the control Pima plants. The load differences between the control and 1-boll-per-branch plants, however, were quite marked throughout the season.

TABLE 3.—*Mean weight of bolls and burs and of seed cotton, fiber, and seeds per boll, in Acala and Pima cotton, from flowers of each period of season (July 1 to September 15, 1928), for each of three treatments*

[Data are based on 100-boll samples]

Period and treatment	Acala					Pima				
	Mean weight of open bolls	Mean weight of burs	Mean weight of seed cotton	Mean weight of fiber [a]	Mean weight of seed [a]	Mean weight of open bolls	Mean weight of burs	Mean weight of seed cotton	Mean weight of fiber	Mean weight of seed
	Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*
First period (from flowers of July 1 to Aug. 4):										
1 boll per branch	10.79	2.82	7.97±0.071	2.56	5.11	4.76	1.36	3.40±0.042	0.94	2.41
Control	9.17	2.12	7.05± .074	2.38	4.49	4.34	1.05	3.29± .038	.89	2.25
Early deflorated	8.72	2.13	6.59± .088	2.23	4.30	4.32	1.16	3.16± .013	.83	2.11
Second period (from flowers of Aug. 5 to 22):										
1 boll per branch	10.62	3.17	7.45± .092	2.43	4.84	5.26	1.74	3.52± .041	.97	2.55
Control	8.87	2.18	6.69± .081	2.21	4.42	3.90	1.02	2.88± .039	.79	2.06
Early deflorated	8.65	2.14	6.51± .109	2.25	4.01	4.54	1.19	3.35± .045	.89	2.23
Third period (from flowers of Aug. 23 to Sept. 15):										
1 boll per branch						5.64	1.83	3.81± .042	1.05	2.57
Control						3.64	.98	2.66± .047	.79	1.84
Early deflorated						3.95	.97	2.98± .057	.88	1.90

[a] Owing to losses in ginning, including foreign material and changes in moisture, the combined weights of fiber and seed do not equal seed cotton per boll.

The bolls of the Acala 1-boll-per-branch plants (Table 3) averaged, respectively, 18 and 20 per cent heavier for the first and second periods than did those of the control plants. The difference between the mean weight of individual bolls on the control and on the early-deflorated plants in the two periods was 5 and 2 per cent, respectively, the bolls being slightly smaller on the early-deflorated plants.

The burs were 33 and 45 per cent heavier on the 1-boll-per-branch Acala plants in the two respective periods, but only a small difference is shown between the burs of the control and the early-deflorated plants. (Fig. 2.)

In Acala the weight of the seed cotton per boll for the three treatments also stands in inverse order to the number of bolls per plant, which was greatest on the early-deflorated plants and least on the 1-boll-per-branch plants. The mean seed-cotton weight per boll on the 1-boll-per-branch plants exceeded that of the control plants by 13 per cent in the first period and by 11 per cent in the second. There was less seed cotton per boll on the early-deflorated plants than on the control plants. Early defloration resulted in a marked decrease in weight of seed in bolls from the second period, but the weight of fiber per boll was not decreased. The weight of fiber and seed per boll was distinctly greater for the bolls from the 1-boll-per-branch plants than for the other treatments.

In the Pima variety (Table 3), limiting bolls to the first nodes materially increased the weight of the individual bolls and of the burs, seed cotton, seed, and fiber per boll. The greatest differences shown by this variety were in the bolls from the third-period flowers. The mean weight of seed cotton per boll was 43 per cent greater and the weight of fiber per boll 33 per cent greater on the 1-boll-per-branch plants than on the controls. Of the increases in weight of the various parts of the boll, that of the bur was greatest, being 86 per cent.

The weight of control Pima bolls and of the different boll fractions decreased as the season progressed, whereas those of the 1-boll-per-branch plants increased.

A cessation in growth of the control Pima plants was quite noticeable in late August and September. The early-deflorated Pima plants, however, continued their growth throughout the late summer.

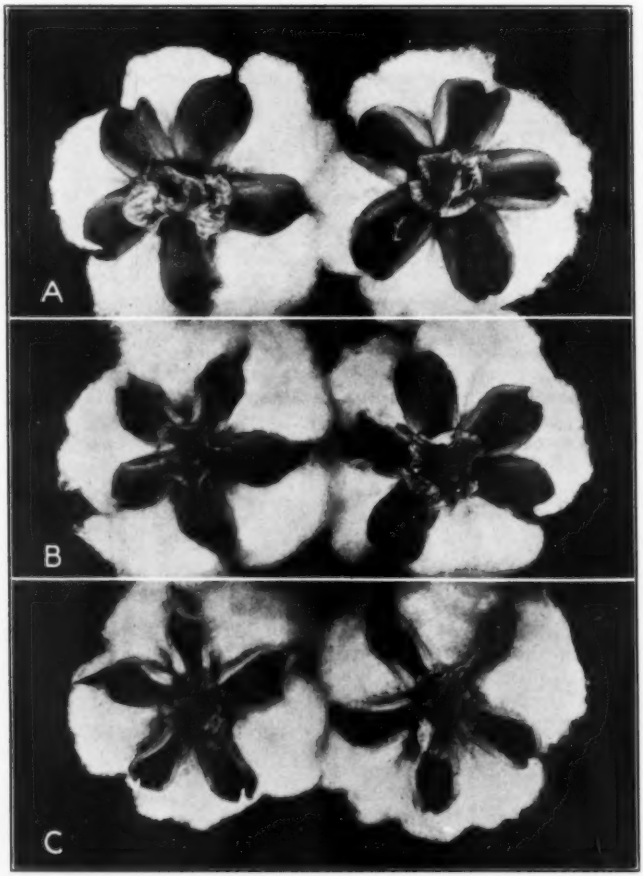

FIGURE 2.—Open Acala bolls from flowers of the second period. × about ½. A, From the 1-boll-per-branch plants. The enlarged burs are to be noted particularly. B, From the control plants. C, From the early-deflorated plants

Table 3 shows the differences between the weight of bolls and boll components of the control and of the early-deflorated Pima plants as being somewhat uncertain during the first period. During the second and third periods, however, the values for the bolls and boll components of the early-deflorated Pima plants are definitely larger in all measurements, except those for third period bolls, than those of the

control plants. The control Pima plants were considered as being more heavily laden with respect to their size than the early-deflorated plants.

In general, the weight of the burs was influenced to a greater extent by the treatments than the weight of the seed cotton, and the weight of the seed to a greater extent than the weight of the fiber. (See also ratios in Table 1 and seed weights in Table 5.)

NUMBER OF LOCKS PER BOLL, SEEDS PER LOCK, AND IMPERFECT SEEDS

If nutritional factors influence the number of locks per boll, and it seems logical that they should, one would expect to find a greater number of locks in bolls on the 1-boll-per-branch plants than in bolls on the control plants, particularly in bolls from the third-period flowers. The number of locks per boll must be determined at a very early stage in the development of the buds. The data (Table 4) do not show significant indications of a nutritional relationship, though many of the differences are in the directions that might be expected.

TABLE 4.—*Percentage of 5-lock and 4-lock bolls for Acala and Pima, respectively, and mean number of seeds per lock and of motes and imperfect seeds per boll in Acala and Pima cotton, from flowers of each period of season (July 1 to September 15, 1928), for each of three treatments*

[Data are based on 100-boll samples]

Period and treatment	Acala			
	5-lock bolls	Mean seeds per lock	Mean motes per boll	Imperfect seeds per boll
	Per cent	*Number*	*Number*	*Number*
First period (from flowers of July 1 to Aug. 4):				
1 boll per branch	91±1.9	7.27±0.082	11.41±0.316	
Control	86±2.4	7.36± .090	10.73± .442	
Early deflorated	87±2.3	7.04± .098	11.40± .355	
Second period (from flowers of Aug. 5 to 22):				
1 boll per branch	75±2.9	7.24± .105	9.48± .350	1.08±0.147
Control	74±3.0	7.63± .085	6.95± .237	1.43± .234
Early deflorated	70±3.1	7.07± .114	8.30± .297	3.38± .412
Third period (from flowers of Aug. 23 to Sept. 15):				
1 boll per branch	[a] 50±3.6	7.44	9.42	.77
Control	[b] 48±6.7	7.52	6.2	1.80
Early deflorated				

Period and treatment	Pima			
	4-lock bolls	Mean seeds per lock	Mean motes per boll	Imperfect seeds per boll
	Per cent	*Number*	*Number*	*Number*
First period (from flowers of July 1 to Aug. 4):				
1 boll per branch	10±2.0	6.19±0.069	3.90±0.136	
Control	16±5.5	6.12± .071	4.20± .145	
Early deflorated	6±1.6	5.84± .084	4.50± .147	
Second period (from flowers of Aug. 5 to 22):				
1 boll per branch	5±1.5	6.18± .077	3.26± .175	0
Control	6±1.6	5.81± .116	3.93± .123	.12±0.043
Early deflorated	10±2.0	5.97± .104	3.95± .152	.11± .037
Third period (from flowers of Aug. 23 to Sept. 15):				
1 boll per branch	6±1.6	6.32± .107	2.68± .123	.09± .053
Control	0±0	5.79± .084	2.77± .138	.52± .090
Early deflorated	4±1.4	5.63± .111	2.84± .141	1.34± .196

[a] 90 bolls. [b] 25 bolls.

There are certain statistically significant variations in the number of seeds per lock at different periods in the different treatments. These effects, however, are in opposite directions in the two varieties. The control Acala cotton appears to have had more seeds per lock than the 1-boll-per-branch Acala in each of the three periods, but in Pima the relationship is reversed. Conversely, a significantly smaller number of aborted ovules, or motes, per boll occurred in the control Acala bolls during the second period than in the 1-boll-per-branch bolls or in the early-deflorated bolls. In the Pima variety the number of motes per boll for the second period was significantly greater in the control and early-deflorated plants than in the 1-boll-per-branch plants.

Imperfect seeds were not sufficiently abundant in Acala seed cotton of the first period to appear noteworthy. The number of these in the cotton of the second period, however, attracted attention, and they were counted. Three, four, and ten per cent of the second-period seeds were found to be imperfect in the 1-boll-per-branch, control, and early-deflorated cotton, respectively. Imperfect seeds are smaller than normal seeds, and the fiber attached to them is short and wasty. Fiber of this character may be a contributing factor to the neps found after ginning and adds to the quantity of waste to be taken from the cotton by the mills. Less than one-fourth of the cotton from the early-deflorated plants, however, was produced from the second-period flowers.

The second-period early-deflorated Acala cotton, as may be noted in Figure 3, contained some foreign material in the form of pieces of seed coats torn from the imperfect seeds in ginning. The cotton from the control plants contained fewer neps than that from the early-deflorated plants, but in no respect other than in length was the control cotton of as high a quality as the fiber from the 1-boll-per-branch plants.

TABLE 5.—*Mean weight per seed of three 25-gm. samples each of Acala and Pima seed, from flowers of each period of season (July 1 to September 15, 1928), for each of three treatments*

Period and treatment	Acala				Pima			
	Lot No. 1	Lot No. 2	Lot No. 3	Mean	Lot No. 1	Lot No. 2	Lot No. 3	Mean
First period (from flowers of July 1 to Aug. 4):	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*
1 boll per branch	0.149	0.150	0.152	0.150	0.135	0.138	0.133	0.135
Control	.135	.137	.134	.135	.124	.123	.124	.124
Early deflorated	.132	.133	.132	.132	.130	.129	.126	.128
Second period (from flowers of Aug. 5 to 22):								
1 boll per branch	.142	.142	.141	.142	.135	.136	.136	.136
Control	.127	.123	.124	.125	.120	.117	.115	.117
Early deflorated	.124	.123	.118	.122	.126	.124	.123	.124
Third period (from flowers of Aug. 23 to Sept. 15):								
1 boll per branch	.142	.146	.137	.142	.135	.137	.133	.135
Control	.130	.133	.130	.131	.115	.113	.111	.113
Early deflorated					.110	.114	.114	.113

MEAN WEIGHT OF SEEDS

In both the Acala and Pima varieties the heaviest seeds were produced by the 1-boll-per-branch plants in each of the three periods (Table 5); the differences for the means of triplicate 25-gm. samples

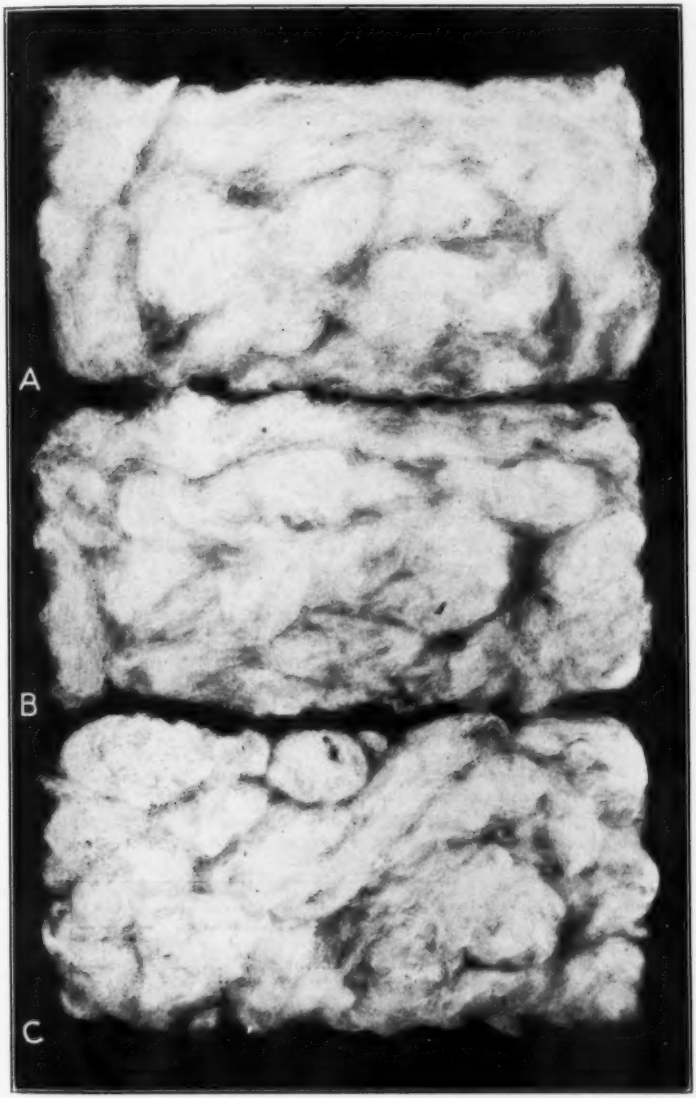

FIGURE 3.—Roller-ginned Acala cotton from flowers of second period. A, One-boll-per-branch cotton. This was superior to either B or C. B, Control. C, Early-deflorated cotton. Foreign material in the form of pieces of seed coats torn from imperfect seed in ginning is to be noted in this sample. It contained the greatest number of neps. Significant differences were not noted between the control and the early-deflorated cotton of the first period, which cotton constituted the bulk of the crop in each case

varied from 8 to 19 per cent. Seeds from the control Acala plants in nearly all cases were heavier than those from the early-deflorated plants, but the differences were not marked. Seeds from the early-deflorated Pima plants were heavier than seeds from the control plants except in the last period, where no difference in average weights was found.

In both varieties the seed weight appears to decrease as the boll load on the plants increases with respect to plant size.

SEED FUZZINESS

Kearney and Harrison [6] have reported that, in Arizona, seeds in bolls produced on higher fruiting branches and at fruiting-branch nodes farther removed from the main axis of Pima Egyptian cotton plants have less fuzz on them than have seeds on lower branches and on nodes near the main axis of the plant. Seeds produced under the different treatments herein described were examined for variations in this character, but no evidence was found that the differences in the nutritional relationships of these plants caused marked differences in seed fuzziness.

LENGTH OF FIBER

The length of both Acala and Pima fiber (Table 6) produced from flowers of the second period was longer than that from flowers of the first period. The treatments did not influence this character during the first period, and no material difference was found in the second period. The difference in length between the Acala fiber from the 1-boll-per-branch plants and that from the early-deflorated plants of the second period is 0.4 ± 0.10 grade,[7] which is significant, the fiber from the 1-boll-per-branch plants being the longer; but no difference was found between the 1-boll-per-branch plants and the control plants. The results obtained indicate that the number of bolls carried by these plants did not influence the length of fiber to the extent that it did other characters previously discussed.

TABLE 6.—*Relative mean length* [a] *of unginned fiber in Acala and Pima cotton, from flowers of each period of season (July 1 to September 15, 1928), for each of three treatments*

[Values represent mean length of fibers attached to 20 seeds, each seed from a different boll selected at random from 100-boll samples]

Period and treatment	Acala	Pima
	Grade	*Grade*
First period (from flowers of July 1 to August 4):		
1 boll per branch	4.0±0.07	7.9±0.07
Control	3.9± .04	8.0± .05
Early deflorated	3.9± .07	8.1± .06
Second period (from flowers of August 5 to 22):		
1 boll per branch	4.4± .07	8.9± .06
Control	4.4± .13	8.7± .05
Early deflorated	4.0± .07	8.0± .04
Third period (from flowers of August 23 to September 15):		
1 boll per branch		7.2± .03
Control		7.2± .03
Early deflorated		7.1± .08

[a] A grade difference of 1 equals one-eighth inch. The grade 4, for example, corresponds to combed fiber ends 1¼ inches from center line of seed.

[6] KEARNEY, T. H., and HARRISON, G. J. VARIATIONS IN SEED FUZZINESS ON INDIVIDUAL PLANTS OF PIMA COTTON IN ARIZONA. Jour. Agr. Research 37: 465–472, illus. 1928.

[7] The length of fiber was measured by the method of "grade" as devised by Kearney: KEARNEY, T. H. SEGREGATION AND CORRELATION OF CHARACTERS IN AN UPLAND-EGYPTIAN COTTON HYBRID. U. S. Dept. Agr. Dept. Bul. 1164, 58 p., illus. 1923.

BOLL-MATURATION PERIODS

Information as to the influence of the plant load on the maturation period of the bolls was available from the dated tags placed on each flower during the period from August 5 to August 22, inclusive. These data have been tabulated only for a comparison between the 1-boll-per-branch plants and the early-deflorated plants. The results of this comparison are given in Table 7.

TABLE 7.—*Mean date of flowering and mean days from flower to open boll for 1-boll-per-branch and early-deflorated Acala and Pima plants from August 5 to August 22, inclusive, 1928*

Variety and treatment	Mean date of flowering from August 5 to 22	Mean days from flower to open boll
Acala:		
1 boll per branch	Aug. 13 ° (13.12)	48.3±0.25
Early deflorated	Aug. 11 ° (11.63)	46.5± .15
Difference in boll-maturation periods		+1.8± .29
Pima:		
1 boll per branch	Aug. 14 ° (14.20)	55.6± .13
Early deflorated	Aug. 12 ° (12.70)	57.5± .08
Difference in boll-maturation periods		−1.9± .15

° Fractional date of flowering.

The bolls on the 1-boll-per-branch Acala plants required 1.8 ± 0.29 days longer to mature than did those on the early-deflorated plants. In the Pima variety the relationship is found to be reversed.

These relatively very small differences in length of the boll-maturation periods are considered especially noteworthy in view of the marked effect of seasonal factors upon maturation periods. Pima bolls set in the latter part of the season may require 20 days longer to mature than those set in July.

SUPPLEMENTARY EXPERIMENT TO DETERMINE EFFECT OF MODIFIED EARLY DEFLORATION

In view of the increased yields anticipated as a result of the early defloration of the Acala plants, it seemed desirable that the experiment herein described should be supplemented by a minor experiment in which the early-defloration method was modified for the purpose of securing information as to its possible commercial practicability. Accordingly, on July 9, all bolls, flowers, and squares of considerable size were stripped from alternate plants in an outside row of the same plot in which the main experiment was conducted. The stripped plants again produced open flowers on July 23. As is shown in Table 8, the effect of defruiting and bud removal upon yields in this experiment was similar to that in the more carefully conducted experiment in which the flowers and large squares were systematically removed during the early flowering period. The results indicate a possible increase in yield of more than 25 per cent.

TABLE 8.—*Amount of seed cotton produced by 100 Acala plants from which all bolls, flowers, and large squares had been stripped on July 9, and by alternately spaced control plants*

Treatment	Seed cotton produced		
	First picking (Oct. 10)	Second picking (Jan. 3)	Total for season
	Pounds	*Pounds*	*Pounds*
Stripped	26.3	4.4	30.7
Control	19.0	4.7	23.7

CLASSIFICATION OF SAMPLES BY BUREAU OF AGRICULTURAL ECONOMICS

After the field-laboratory examinations had been completed, samples of the ginned cotton from the second period of the main experiment with Acala and Pima and from both pickings of the supplementary experiment with Acala were forwarded to the Bureau of Agricultural Economics for independent classification. The results of this classification are given in Table 9.

TABLE 9.—*Classification of cotton samples by Bureau of Agricultural Economics* [a]

Experiment, variety, and treatment	Grade [b]	Length of staple [c]	Fiber (body)	Strength	Remarks
Major experiment, second period, roller ginned:					
Acala—		*Inches*			
1 boll per branch	GM E. W. [d]	1 3/32	Medium	Fair	Fairly free of neps.
Control	do	1 3/32	do	do	Do.
Early deflorated	SM E. W	1 1/16	do	do	Slightly neppy.
Pima—					
1 boll per branch	No. 1/2 A. E. [e]	1 7/8	Fine	Strong	Good character.
Control	N. 2 A. E	1 5/8	do	Normal	Slightly neppy.
Early deflorated	do	1 3/4	do	Strong	Good character.
Supplementary experiment, saw ginned:					
Picked Oct. 10 (three-fourths of crop)—					
Acala—					
Control	SM E. W	1 1/32	Medium	Normal	Neppy.
Early bolls and buds stripped	do	1 1/32	do	do	Less neps than control.
Picked Jan. 3 (one-fourth of crop)—					
Acala:					
Control	do	1 1/16	do	do	Neppy.
Early bolls and buds stripped	do	1 1/16	do	do	Neppy, equal to control.

[a] Under the direction of A. W. Palmer.
[b] GM E. W. is Good Middling Extra White; SM E. W. is Strict Middling Extra White.
[c] Average uniformity of length was regular in all cases.
[d] Extra-white standards.
[e] American-Egyptian standards.

The cotton classers differentiated between the early-deflorated and the control Acala from the second period with respect to grade, length of staple, and number of neps. The most outstanding difference was expected from the cotton of the second period, but this cotton constituted only a small portion of the entire crop. It will be noted that the early-deflorated Acala plants, which carried the heaviest loads of bolls, produced 1/32-inch shorter lint during the

second period than the control or the 1-boll-per-branch plants of this variety, the difference being nearly the same as that indicated by the method of grade in Table 6. The early-deflorated Pima plants, while not more heavily laden in proportion to their size, nevertheless produced 24 per cent more cotton than the control plants, and the cotton classers' report shows that the early-deflorated cotton was of higher quality than the cotton produced by the control plants.

The cotton classers differentiated between the samples from the supplementary experiment with Acala only in the number of neps. Confirming observations of the writer and of others who examined the samples, the cotton classers found that the cotton from the control plants contained more neps than that from plants whose yields had been increased by more than 25 per cent by the removal of early bolls and squares. The latter result indicates that early defloration, or stripping, as a method of increasing yields is warranted from the standpoint of the quality of the fiber produced.

SUMMARY AND CONCLUSIONS

An experiment was conducted with the Acala upland and the Pima Egyptian varieties of cotton, for the purpose of determining (1) whether yields could be increased by delaying for several weeks the initiation of flowering and boll setting, and (2) the effect of both an increased and a decreased number of bolls per plant upon the characteristics of the bolls and fiber produced.

The modifications in the number of bolls per plant were brought about in two ways: (1) By allowing a boll to develop only at the first node of any fruiting branch, and (2) by removing all flowers during the first 25 days of the flowering period. The results of these treatments were checked against the number of bolls produced by untreated control plants. The resultant yields in number of bolls per plant were: For Acala, 10.7 and 20.1 from 1-boll-per-branch and early-deflorated plants, respectively, as against 16.8 from untreated plants; and for Pima, 16.6 and 49.9 from 1-boll-per-branch and early-deflorated plants, respectively, as against 42.4 from untreated plants. While the effect of the first treatment was to decrease the number of bolls, substantially increased yields resulted from the second treatment (early defloration) in both varieties, irrespective of whether the yields were measured in terms of the number of bolls, the weight of the seed cotton, or the weight of the fiber produced.

An increase of more than 24 per cent in the yield of Acala cotton was obtained in a supplementary experiment in which all bolls and flowers and the larger squares were stripped from 100 plants alternately spaced with control plants. The plants were treated in this manner on the eighth day of the flowering period, and they again produced flowers 14 days later. The method used in this experiment may prove practicable commercially, and the increased yields obtained from it indicate that it might be profitable.

An inverse relation was found, in both Acala and Pima, between the number of bolls per plant and the mean weights of the open bolls and burs and of seed cotton per boll and seed per boll (also Pima fiber per boll) for the bolls resulting from the second-period flowers (August 5 to 22). It was not until the latter part of the summer that the early-deflorated Pima plants had set a greater number of

bolls than the control plants, and, in the characters mentioned above, the early-deflorated Pima plants were intermediate between the 1-boll-per-branch and the control plants. In general the weight of the burs was influenced by the treatments to a greater extent than the weight of the seed cotton, and the weight of the seed more than the weight of the fiber.

The treatments did not result in significant differences in the number of locks per boll, nor did they materially influence boll-maturation period.

The classification of the Acala cotton from the second-period flowers brought out differences which favored the fiber from the 1-boll-per-branch and the control plants. In samples representing both pickings from the supplementary Acala experiment, the only differences were in the number of neps; fewer neps were found in the samples from plants stripped of early bolls and buds.

The cotton from Pima 1-boll-per-branch plants received the highest ratings, that from the early-deflorated plants being intermediate and that from the control plants lowest.

It has been observed that the yields of determinate strains of cotton are lower than the yields of strains that ordinarily abort a considerable number of their early buds and bolls. The Acala strain used in experiments herein reported has proved to be less determinate in its growth and better suited to Arizona conditions than other strains with which it has been compared.

The marked increase in yields obtained by early defloration is particularly noteworthy in view of the fact that similar results were obtained with both the upland Acala and the Pima Egyptian varieties, which are very different, not only in their morphological but also in many of their physiological characteristics.

SOME NEMIC PARASITES (OXYURIDAE) OF COLEOPTEROUS LARVAE[1]

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INTRODUCTION

No group of nemas is found in a greater variety of hosts than the Oxyuridae. Representatives occur in every class of vertebrates and in addition are common parasites of vast numbers of invertebrates.

Early investigators of this group, inspired by an interest almost purely scientific, studied and described a considerable number of not very closely related species from both vertebrate and invertebrate hosts, placing them in the genus Oxyuris. Subsequent workers, influenced by an increased emphasis placed on the economic phases of helminthology, devoted their efforts largely to parasites infesting vertebrates, especially domesticated animals and man. As a result of this intensified study, the genus Oxyuris, as originally conceived, has been broken up into about 60 genera. But until recently the nemic parasites occurring in invertebrates have received scant attention, and many of the early described species are still carried in the literature, including various textbooks, as belonging to the genus Oxyuris, although in the modern conception of the genus this is obviously incorrect.

During the last decade the ever-increasing appreciation of the value of parasites in controlling injurious insects has caused nematologists to realize that the nemic parasites of invertebrates may be of more than purely scientific importance and to view them with renewed interest. The probable economic rôle of some of these forms, including several of the oxyurids, has already been demonstrated. Among them may be mentioned *Neoaplectana glaseri* Steiner (*8*),[3] infesting the larvae of the Japanese beetle, *Popillia japonica* Newman.

These oxyurids of invertebrates present many difficulties to one who would contribute to the knowledge of their taxonomy. In the first place, taking the group as a whole, the characters that have been most used, not only as a basis for separation into major groups but also as a means of identifying genera and species, are largely characters of the male. Among nemas infesting insects are many species the males of which are either rarely seen or unknown, and in those cases where males are found there is often a pronounced sexual dimorphism. This dimorphism involves not only size and sexual characters but many other characters as well. For example, females may have conspicuous papillae on the head, whereas on males of the same species these papillae are either absent or so reduced as to be indis-

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[2] The writer is indebted to Gertrude L. Power, formerly of the Office of Nematology, Bureau of Plant Industry, U. S. Department of Agriculture, for assistance in conducting the investigations and in preparing the drawings and manuscript; to A. G. Böving, Bureau of Entomology, U. S. Department of Agriculture, for identification of the host insects; and to Frank Blanchard, University of Michigan, for collecting and sending the insects from which a large number of the parasites were obtained.

[3] Reference is made by number (italic) to Literature Cited, p. 482.

tinguishable. The shape of the head, the character of the pharynx, the shape of the esophagus, and many other structures may show considerable variation between the two sexes. Hence, in cases where two or more species inhabit the same insect host, the matching of males and females may become an exceedingly perplexing problem.

Investigation of marine and many other free-living species has shown that a female containing mature ova is nearly full grown, so that corresponding measurements of a number of such females of the same species will be fairly uniform. This is less likely to be true of the oxyurids of insects. In some species a female may nearly double in size (by increasing in both length and breadth) after she has begun depositing eggs. The growth of such females has already been noted by Bütschli (*1*), Steiner (*7*), and others. To some extent a corresponding growth seems to occur in sexually mature males. Another cause of variation in measurements is found in the ability of the parasites to elongate or shorten the anterior or neck region of the body. In the living specimen the length of the neck and the relative position of such structures as the nerve ring and the excretory pore are not necessarily constant, and in fixed material the variation may be even more noticeable. This subject is mentioned, not with a view to belittling the value of measurements, but in order to point out certain facts that must be given consideration in comparing individuals.

In the following formulas the writer has not attempted to give the limits of variation, but has taken measurements from the largest specimens available.

TERMS

Amphids.—This term is used here to include all structures, both internal and external, which go to make up these sense organs. The appearance of the amphids at the points where they open to the exterior, as seen when the head is viewed from the front, is referred to as their external manifestation. This does not always indicate a purely surface demarcation, but may result partly from an enlargement of the tube leading backward, which, lying just below the cuticle, may be seen through it. This enlargement is referred to as the vestibule.

Isthmus.—That part of the esophagus between the anterior portion and the cardiac bulb, often set off from the former by a distinct constriction, is referred to as the isthmus, a term which has already been used with this meaning. The isthmus is, strictly speaking, the anterior neck of the cardiac bulb.

Myolabia.—Cobb (*2*) has recently expressed the opinion that the eight cephalic elevations occurring on the head of the female of *Thelastoma attenuatum* Leidy are the external manifestations of the muscle fields and has proposed for them the name myolabia. After studying a considerable number of species of this and related genera, the writer is not inclined to regard the elevations as lips. On the head of the female of *Hystrignathus rigidus* Leidy, corresponding exactly to the myolabia of *T. attenuatum*, are eight elevations which the writer believes any nematologist would unhesitatingly designate as papillae. Only slightly less papilloid in character are the innervated cephalic elevations on the head of the female of *T. papilliferum*, n. sp. On the female of *T. macramphidum*, n. sp., one finds similarly placed elevations, more or less papilloid but without apparent nerve endings. In the female of *Blatticola blatticola* (Galeb) these structures are broad,

considerably flattened, and more or less incurved, a condition likewise found in the female of *Aorurus subcloatus*, n. sp., although in the latter the elevations are subrectangular in outline when seen from the front. In *Scarabanema cylindricum*, n sp., these structures are not sufficiently elevated to break noticeably the even contour of the head, but when seen from the front their margins form a faint scroll-like pattern around the mouth. The structures in *Binema ornata* Travassos and *B. binema* Travassos are large and considerably elevated, similar to but somewhat larger than those of *T. attenuatum*, and they assume a truly labiumlike character. The head of the female of *T. robustum* Leidy is more or less intermediate between the extreme condition found in *T. myolabiatum* Cobb and the more common condition found in such forms as *Binema binema*. The head of *T. robustum*, when viewed from the front, is distinctly 8-lobed, but the lobes are not so deeply cut nor do they extend toward the mouth as in *T. myolabiatum*. But the head of *T. robustum* also bears the eight smaller lobelike elevations pointing inward toward the mouth and somewhat resembling those of *Blatticola blatticola*. To which of the two subgenera of Thelastoma proposed by Cobb such a species as *T. robustum* should belong is problematical.

Failure to see nerve endings in these cephalic elevations merely means that they are not conspicuously innervated. It is the writer's opinion that throughout the series (with the possible exception of *Thelastoma myolabiatum*) these structures are homologous and that ontogenetically they are papillae. Myolabia may be an appropriate term for the structures as found on the heads of *T. myolabiatum*, *T. robustum*, *Binema binema*, and others, where they are more or less labial in character. To apply it to the distinctly papilloid structures of *Hystrignathus rigidus* and *T. papilliferum* would, it seems, lead to confusion. At what point in the series they cease to be papillae and become myolabia is another matter, and one which at present is not altogether clear.

The posterior end of the alimentary tract (see fig. 3, A) of many scarabaeid larvae is pronouncedly enlarged, and the food material contained therein gives the posterior part of the animal its characteristic dark appearance. This region of the intestine has been referred to by some German helminthologists as the "Blinddarm," although it is not, strictly speaking, a caecum, but rather a greatly dilated convolution in the posterior part of the intestine. This intestinal enlargement is the habitat of several nemic species, including those dealt with in this paper.

TAXONOMY

The information furnished in the following keys should serve as a brief diagnosis by which the related genera and species may be differentiated. An attempt has been made to include in the key to the genera a sufficient number of characters to differentiate them, not only from one another but from related genera. At present the genus Thelastoma is in a very confused condition. It contains a considerable number of species, many of which have been inadequately studied and described, and some of which obviously do not belong to the genus. Until the whole group has been carefully worked over, it is impossible to key the genus or provide any given species with a specific diagnosis that will positively differentiate it from all other species of the genus.

KEY TO THE GENERA

1. Female with distinct, subspherical median bulblike enlargement of the esophagus ..... Aorurus
   Female without distinct median bulblike enlargement of the esophagus. Cephalic elevations (papillae or myolabia?), when present, eight in number, never four; ovaries two. Male with spicule 2
2. Total length of female, up to 5 mm.; slender, pointed caudal spike; external amphids elliptical, comparatively large; anus of male strongly salient; papillae grouped close to anus except for pair on caudal spike; excretory pore (both sexes) near cardiac bulb ..... Thelastoma
   Total length of female, up to 8 mm.; short, conical, blunt posterior terminus. External amphids very small, nearly circular; anus of male not strongly salient; most anterior pair of papillae somewhat removed from anus; excretory pore (both sexes) posterior to cardiac bulb by a distance greater than the corresponding body diameter ..... Scarabanema

KEY TO THE SPECIES OF THELASTOMA DESCRIBED IN THIS PAPER

1. Vulva distinctly salient; external amphids (both sexes) very large; female head with four broad, lobelike elevations without apparent innervation ..... *T. macramphidum*
   Vulva not distinctly salient; external amphids (both sexes) of moderate size; female head with four distinctly papilloid, innervated elevations ..... *T. papilliferum*

KEY TO THE KNOWN SPECIES OF AORURUS

1. Vulva near anus ..... *A. subcloatus*
   Vulva not near anus, nearer middle of body 2
2. Isthmus twice as long as broad; neck region elongated; annules very wide; parasites of Blattidae ..... *A. diesingii*
   Isthmus as wide as or wider than long; neck region not elongated, annules of moderate width; parasites of Myriopoda ..... *A. agile*

KEY TO THE KNOWN SPECIES OF SCARABANEMA

1. With three conspicuous, yellowish bodies near the vagina ..... *S. leuckarti*
   Without conspicuous bodies near vagina 2
2. Ova much elongated, 89μ long by 26μ in diameter ..... *S. brevicaudatum*
   Ova less elongated, 70μ long by 45μ in diameter ..... *S. cylindricum*

FAMILY OXYURIDAE

GENUS SCARABANEMA, N. G.

Scarabanema, n. g.

GENERIC DIAGNOSIS:

Female.—Body comparatively long, nearly cylindrical, its maximum diameter somewhat anterior to the middle. Caudal spike conical, short. Pharynx very short, sometimes armed with three teeth. Anterior portion of esophagus nearly cylindrical, contracted where it joins isthmus, the latter short but distinct, with a diameter distinctly less than the anterior portion of the esophagus. Cardiac bulb nearly spherical. Excretory pore posterior to cardiac bulb. Excretory ducts very large and conspicuous. Ova, as compared with size of body, small (in known species 70μ to 100μ long by 25μ to 70μ broad), numerous (in *S. cylindricum* 800 to 1,000), not distinctly flattened on one side. Reproductive system double, vulva near middle of body.

Male.—Much smaller than female. Tail ending in slender caudal spike; anus but slightly salient. A pair of papillae (one right and one left) somewhat anterior to the anus, probably a pair of weakly developed papillae opposite the anus, a single median duplex papilla slightly posterior to the anus, and a pair of papillae on the base of the caudal spike. Excretory pore posterior to cardiac bulb,

Parasites of the posterior end of the intestine of coleopterous larvæ of the family Scarabaeidae.

Type species.—*Scarabanema cylindricum*, n. sp.

Scarabanema cylindricum, n. sp. (Figs. 1 to 5, inc.)

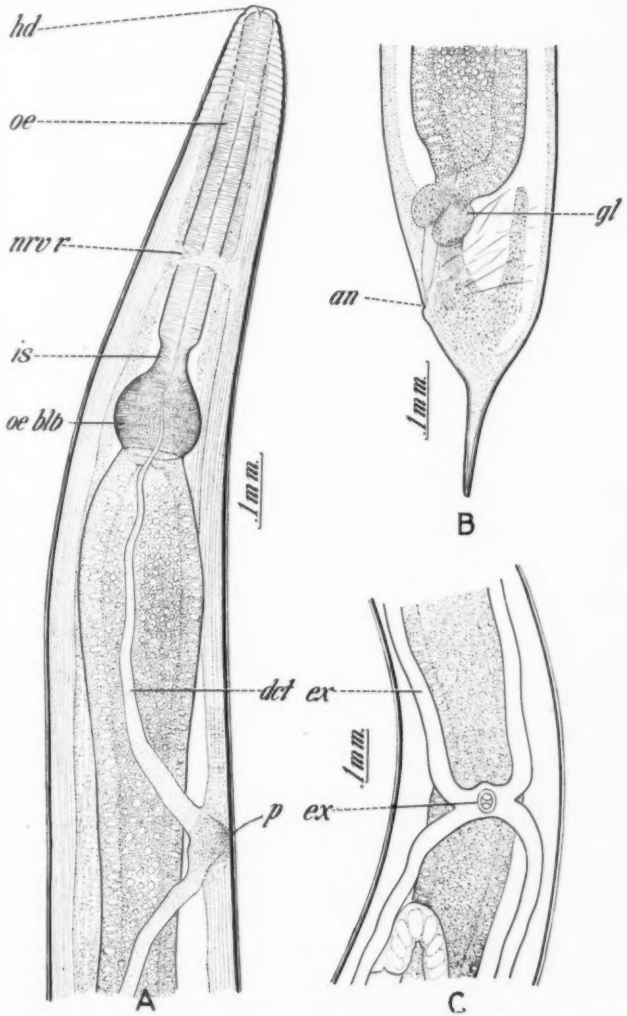

FIGURE 1.—*Scarabanema cylindricum*, ♀: A, Anterior end, lateral view; *hd*, head; *oe*, esophagus; *nrv r*, nerve ring; *is*, isthmus; *oe blb*, esophageal bulb; *dct ex*, excretory duct; *p ex*, excretory pore; B, posterior end, lateral view; *gl*, gland; *an*, anus; C, excretory pore and ducts, ventral view; *dct ex*, excretory duct; *p ex*, excretory pore

Female:

5.4	10.	'52'	96.	6 mm.
2.4	3.4	5.4	2.4	

The body is nearly cylindrical, 3.5 to 6 mm. long. The cuticle is traversed by coarse, transverse striae from 6μ to 10μ apart. On the posterior portion of the body, at varying intervals, usually from 0.1 mm. to 0.2 mm. apart, a transverse stria takes the form of a rather pronounced groove. Alae are not present. The head is subtruncate, with a constriction setting off a head region (fig. 1, A), 10μ long. The first annule back of the head region is 15μ to 18μ wide. The anterior 10 to 12 annules are more conspicuous than those elsewhere on the body, giving the anterior part of the conoid neck region a crenate contour. When seen from the front the subtriangular mouth is without lips and is surrounded by eight rather faint, more or less incurved, very slightly elevated, lobelike structures (fig. 2, B), not distinctly papilloid in appearance and not observed to be innervated. The rather conspicuous, small, faintly elliptical, amphidial markings (fig. 2, B) occupy the usual positions on the anterior outer margin of the head. The simple, very short, conical pharynx (fig. 2, C) is armed at the base with three structures which, when the head is seen in profile, appear as sharp, inward-pointing and forward-pointing teeth, but when viewed from in front (fig. 2, B) have the appearance of broad, triangular plates. The esophagus enlarges very slightly

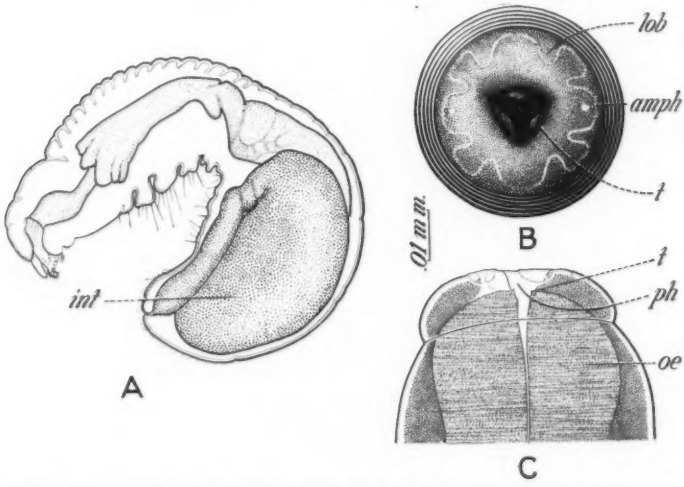

FIGURE 2.—A, Digestive tract in typical scarabaeid larva; *int*, intestine; B, *Scarabanema cylindricum*, ♀, end view of head; *lob*, lobe; *amph*, amphid; *t*, tooth; C, *Scarabanema cylindricum*, ♀, dorsal view of head, *t*, tooth; *ph*, pharynx; *oe*, esophagus

where it joins the pharynx. The anterior portion (fig. 1, A) is nearly cylindrical, increasing slightly and gradually in diameter posteriad. There is an abrupt reduction in size where it joins the isthmus, the latter having a diameter two-thirds as great as the adjacent end of the anterior portion. The cardiac bulb (fig. 1, A, *oe blb*) is broadly pyriform, and has a diameter equal to about four-sevenths of the corresponding body diameter. It possesses the valvular apparatus characteristic of the group, but the fact is somewhat obscured by the density of the bulb.

The ventriculus varies in different individuals. In some cases the enlargement is rather gradual, whereas in old females the dilation is slightly telescoped over the bulb. Behind the ventriculus the intestine is two-fifths as wide as the corresponding part of the body except at the posterior end, where there is another slight dilation. The more or less straight, conical rectum has a length about equal to the body diameter at the anus. At its junction with the intestine it is surrounded by the usual rectal glands (fig. 1, B), probably three in number. In some specimens the body tapers more or less evenly from the anus to the point of the tail, producing a broad, conical terminus; in others, probably older females, it rounds off back of the anus and is then drawn out into a short, blunt terminal spike, about 0.25 mm. long from the anus.

The excretory system (as in all species here described) is of the H-shaped type. A right and a left posterior branch, contained in the lateral cords, extend down toward the ventral surface as they approach the excretory pore. Here they are joined by two similar anterior branches, all four ducts uniting near the excretory pore, which lies 0.5 mm. back of the cardiac bulb. (Fig. 1, C.) The ducts are very large and conspicuous in the region of the pore (fig. 1, A and C), but distally they become smaller. The nerve ring encircles the esophagus about three-fourths the distance from the head of the isthmus.

The reproductive system is double. The vulva is near the middle of the body and is not salient. The tubular vagina (fig. 3) has a length slightly greater than the corresponding body diameter, and passes anteriad to join the uteri. Usually, in this group of oxyurids, the proximal end of the vagina is differentiated into a region with thicker and more muscular walls and a narrower and sometimes more heavily cuticularized lumen. In this species, however, a differentiation of this character is not very conspicuous, although the walls of the vagina close to the vulva seem slightly more muscular than elsewhere. The general structure and position of the female gonads can best be understood by referring to Figure 3. The ova are ellipsoidal (70μ by 45μ) and are deposited before segmentation.

Male:

9.1 17. 'M 93.
3.3 4. 4.7 2. 1.15 mm.

Body moderately slender, total length 1.15 mm., diameter at middle of body 54μ, caudal spike 80μ long from anus. Cuticle faintly and rather finely striated. In the neck region the annules are 1,5μ to 2μ in width, increasing to about 3μ in the middle of the body. The head is subtruncate, and a wide, almost imperceptible constriction sets off an exceedingly short head region. The pharynx is so short as to be nearly nonexistent. The anterior portion of the esophagus (fig. 4, *oe*) is nearly cylindrical. It is faintly expanded at its anterior end, where its diameter (12μ) nearly equals that of the head region. It is slightly and gradually expanded at the middle, where its diameter (15μ) is

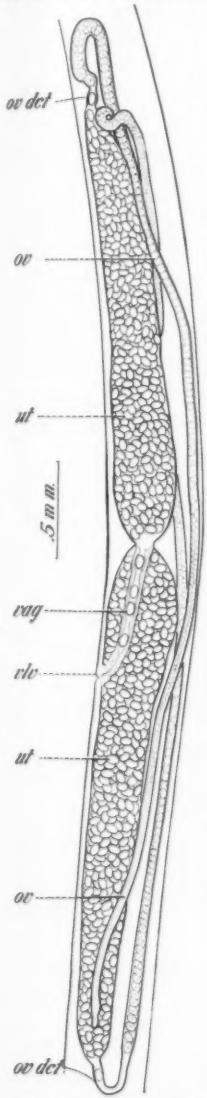

FIGURE 3.—*Scarabanema cylindricum*, ♀, reproductive system, lateral view; *ov dct*, oviduct; *oe*, ovary; *ut*, uterus; *vag*, vagina; *vlv*, vulva

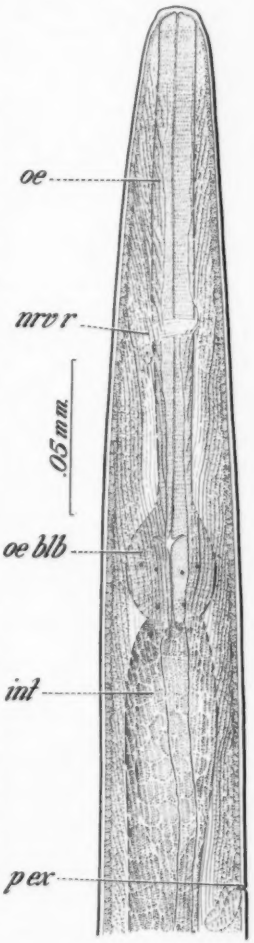

FIGURE 4.—*Scarabanema cylindricum*, ♂, anterior end, lateral view; *oe*, esophagus; *nrv r*, nerve ring; *oe blb*, esophageal bulb; *int*, intestine; *p ex*, excretory pore

about half the corresponding body diameter. It gradually contracts in front of the cardiac bulb (fig. 4, *oe*, *blb*) to a diameter of 11μ, but no distinct isthmus is differentiated. The cardiac bulb is slightly elongated with a diameter of 29μ and a length of about 34μ. The small but rather distinct valvular apparatus is located well forward. The bulb contains at least nine nuclei, probably of the muscle cells.

The intestine (fig. 4) is slightly expanded at its anterior end, the wall in this region being comparatively thin and the lumen correspondingly enlarged, thus forming a rather distinct ventriculus. The rectum has a length (55μ) slightly more than twice the body diameter at the anus (23μ). Exactly what part of this is cloaca was not determined. In the specimen studied the rectum was considerably expanded in the middle. The anus is but slightly salient. The testis is reflexed.

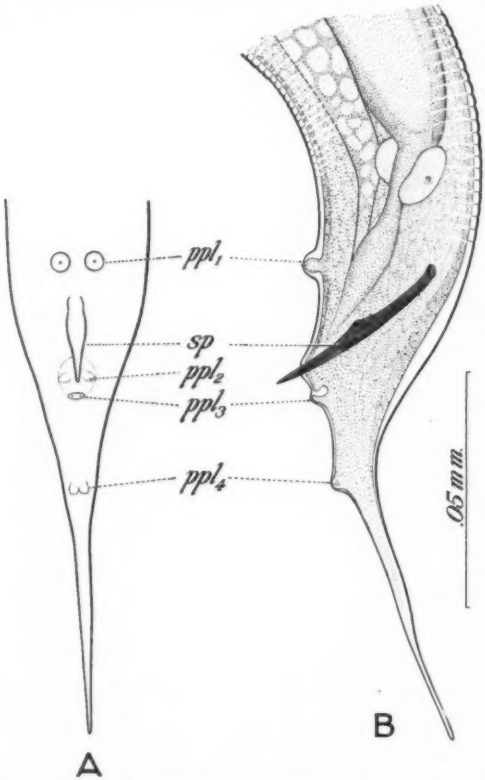

FIGURE 5.—*Scarabanema cylindricum*, ♂: A, Posterior end, ventral view; B, posterior end, lateral view; *sp*, spicule; ppl_1, preanal papillae; ppl_2, papillae, one on each side of anus; ppl_3, median, duplex, postanal papilla; ppl_4, papillae on caudal spike

The spicule (fig. 5, B) is 43μ long, not expanded at the proximal end, and ends distally in a sharp point. It is conspicuously expanded in the middle to a diameter of 5μ, the expansion forming a backward-pointing barb on the antero-ventral side.

A pair (one right and one left) of preanal papillae (fig. 5, A and B) are located 23μ in front of the anus, each being about 4μ high by 6μ broad at the base. A pair of papillae, one on each side of the anus, are evidently present, although they do not stand out conspicuously. Slightly posterior to the anus (5μ) there is a median, duplex papilla with two distinct nerve endings, and there are a pair of papillae on the caudal spike about 25μ back of the anus. In lateral view there appears to be a small, narrow depression immediately in front of the median postanal papilla, covered over with the cuticle; but this could not be seen in ventral view.

Host.—Scarabaeid larvae belonging either to the Melolonthinae or the Rutelinae. Four of these larvae (from three of which *Scarabanema cylindricum* had been removed) were submitted to A. G. Böving[3] of the Bureau of Entomology, United States Department of Agriculture, who reported as follows:

"The four larvae are all the same species, and according to all the characters, with the exception of two, this species belongs to the subfamily Rutelinae.

"Like the rest of the known Rutelinae larvae, it possesses 4-jointed antennae, each of the abnormal segments one to six having three dorsal transversal bulges, densely beset with small thorns; the legs have one distinct claw; below the anus are two almost parallel longitudinal rows of pointed spines and the anal slit forms a simple transverse line. The latter character is very important as it distinctly separates the Rutelinae from the Melolonthinae which have a Y-shaped

[3] BÖVING, A. G. Unpublished report.

anus. Unfortunately only one of the submitted four specimens shows this region intact [in the others it was destroyed during the removal of the parasites], but in this one, the shape of the anus is very evident. The two extraordinary characters referred to above are (1) the presence of 16 to 17 stridulating teeth on the dorsal (buccal) margin of the maxillae—all other Rutelinae have only from 6 to 10—and (2) no stridulating area on the ventral (buccal) side of the mandibles, while all other Rutelinae larvae have a very distinct mandibular stridulating area. The end of each of the mandibles is oblique and without many pointed teeth, just as normal in all Rutelinae as in the Melolonthinae.

"By the deviating maxillar and mandibular stridulating structure the submitted larval form is easily recognized, but in the museum collection of the Rutelinae larvae none of the genera or species represented possesses it, and as far as I know nowhere in the literature is a similar larva described."

Location.—Posterior end of intestine.

Locality.—Woods Hole, Mass., U. S. A.

Type specimens.—United States National Museum Helminthological Collection No. 8108.

Paratypes.—No. 8109.

Technic.—Male specimen killed in hot 60 per cent alcohol, containing 3 per cent glycerin from which the alcohol was evaporated. It was mounted and studied in glycerin jelly. This method of treatment may have resulted in a slight increase in length. Females were studied while living and after various treatments. Formula from specimens stilled with osmic vapor.

Scarabanema leuckarti (Hammerschmidt, 1838).

Synonym.—*Oxyuris brachyura* Hammerschmidt, 1847.

Female.—Body in general cylindrical, neck region distinctly conoid, total length 6.23 to 8.43 mm., maximum diameter 0.423 mm. The nearly cylindrical anterior portion of the esophagus enlarges slightly posteriad, then is abruptly reduced in diameter to form the isthmus. Cardiac bulb oblate. Intestine with club-shaped ventriculus and a lesser posterior dilation. Vulva near middle of body, not salient. Reproductive system double. On either side of the vulva are several (Hammerschmidt figures three) yellowish, spindle-shaped bodies, probably vaginal glands. Eggs ellipsoidal, 84μ to 100μ long by 70μ in breadth.

Male.—Unknown.

Host.—Believed to have been the larvae of *Rhizotrogus aprilianus* and *R. solstitialis*. The accepted names for these insects are now *Amphimallon assimilis* Hbst. and *A. solstitialis* L., respectively.

Location.—Posterior end of intestine (Blinddarm).

Locality.—Germany.

Hammerschmidt first described this species as *Oxyuris leuckarti* in 1838 (*3*). A second paper by this author published in 1847 (*4*) contains the description of *O. brachyura*. While Hammerschmidt does not specifically state that the two names apply to the same species, a careful examination of his descriptions and figures leaves little room for doubt that *O. brachyura* is *O. leuckarti* renamed and redescribed. One would judge that the yellowish bodies situated near the vulva are fairly conspicuous structures not easily overlooked, and as similar bodies could not be found in *Scarabanema cylindricum*, it is concluded that *S. leuckarti* is specifically distinct.

Scarabanema brevicaudatum (Leidy, 1851).

Synonym.—*Aorurus* (*Thelastoma*) *brevicaudatus* (Leidy, 1851) Walton, 1927 (*9*).

Body in general cylindrical, rapidly narrowing anteriad from the cardiac bulb, producing a conical neck region. Body narrows abruptly in anal region, producing a very short spiculate tail. Total length 4.23 mm. (2 lines). Vulva situated slightly posterior to middle of body. Intestine with broad ventriculus and lesser posterior dilation. Anterior portion of esophagus 0.384 mm. long by 38μ in diameter. Cardiac bulb 0.102 mm. long by 89μ in diameter. Ova ellipsoidal, 89μ long by 25μ broad.

Host.—Larva of *Scarabaeus relictus*. The accepted name for this insect is now *Ligyrodes relictus* (Say).

Location.—Intestine.

Locality.—Near Philadelphia, Pa., U. S. A.

The above diagnosis, taken from Leidy's original description (*6*) indicates that this parasite belongs to the genus Scarabanema, but it is scant information upon which to identify the species. In one particular, however, this species appears to differ from either of the other two species of the genus, namely, in the shape of the ova. While in length (one two-hundred-and-eighty-fifth of an inch or about 89μ) they compare favorably with the ova of *S. leuckarti*, they are but 25.4μ (one-thousandth of an inch) broad, indicating a much narrower and more elongate shape. It seems wiser, therefore, for the present to regard *S. brevicaudatum* as a distinct species.

Hammerschmidt was unable to find males of *Scarabanema leuckarti*, although one would judge from his paper that he made some effort to do so. He expressed the opinion that in some cases the males of insect oxyurids are seasonal in their occurrence. Apparently Leidy was also unsuccessful in finding the males of *S. brevicaudatum*. The writer has, over a period of five years, examined many scarabaeid larvae which were infected with the females of *S. cylindricum* in numbers of from one to eight. Although a careful search was always made, no male was found until one male specimen was secured from a beetle larva collected at Woods Hole, Mass., March 17, 1930.

GENUS THELASTOMA LEIDY 1849 (*5*)

Thelastoma (Thelastoma) macramphidum, n. sp. (Figs. 6, 7, and 8.)

Female:

0.6	9.7	22.	'50'	72.	3.5 mm.
1.2	4.0	6.0	7.8	3.4	

Body moderately robust, total length 2.3 to 3.5 mm. Caudal spike 1.1 mm. long from anus. A constriction sets off a distinct head region. (Fig. 6, A.)

The first annule back of the head region is 13μ to 16μ wide and the succeeding annules are 7μ to 8μ, increasing to 12μ or 13μ near the base of the esophagus. Alae are absent. The mouth opening is subtriangular and is bordered by three distinctly elevated lips. (Fig. 7, B and C.) Surrounding the mouth on what may be designated as the outer anterior margin of the head, is a circle of eight elevations which, when viewed from in front (fig. 7, B), appear distinctly oblong, the longest diameter of 6μ to 8μ being perpendicular to the corresponding radial axis of the animal. While they are more or less papillalike, they were not observed to possess nerve endings. The two subdorsal and the two subventral elevations are slightly larger than the sublateral.

The amphids are large and conspicuous, and when seen from in front (fig. 7, B) appear as elliptical markings, 5μ by 3μ, with the longest diameter dorsoventral. This is probably the outline of the vestibule directly below the cuticle, while the actual opening is considerably smaller and takes the form of a broad slit. When viewed dorsoventrally the amphidial vestibule (fig. 7, C) is seen to possess a very heavy wall. From the base of the vestibule the connection was traced posteriad for only a short distance.

The pharynx (fig. 7, C) is about 14μ to 16μ long by 11μ to 13μ in diameter. Each of the three sectors of the esophagus is prolonged into a rounded, somewhat inward-pointing projection extending into the base of the pharynx, and each bears on its inner anterior margin a smaller, somewhat rounded, secondary projection (fig. 7, C, *t*), which might be regarded as a tooth although it does not appear to be very sharp or heavily cuticularized; otherwise the pharynx is plain and unarmed. The anterior portion of the esophagus (fig. 6, A) is of very nearly uniform diameter throughout increasing but slightly and gradually posteriad. The isthmus is separated from it by a distinct constriction and has a diameter very slightly less than that anterior to the constriction.

The intestine is somewhat dilated at its anterior end, forming a ventriculus, but only slightly so at its posterior end. It is not telescoped over the cardiac bulb. The junction of the intestine and rectum is flanked by at least three glands. The anus is not set off by lips. The tail narrows rather abruptly back of the anus and is then extended into a narrow, sharp caudal spike more or less distinctly differentiated from the body proper, closely resembling that of *Thelastoma papilliferum*. (See fig. 9, A.)

The excretory pore is located opposite the cardiac bulb. The ducts of the excretory system are comparatively small and difficult to see in preserved material;

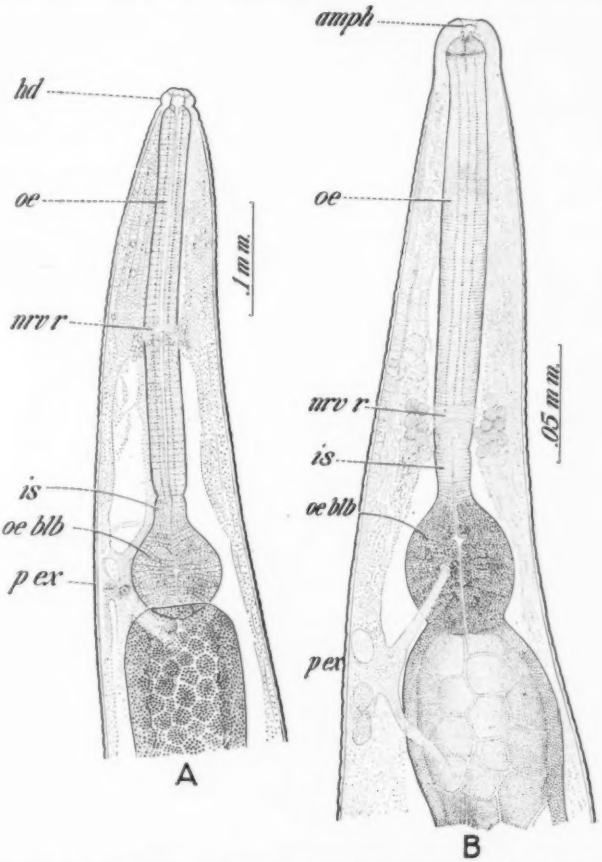

FIGURE 6.—*Thelastoma macramphidum:* A, Anterior end, lateral view, ♀; *hd*, head; *oe*, esophagus; *nrv r*, nerve ring; *is*, isthmus; *oe blb*, esophageal bulb; *p ex*, excretory pore; B, anterior end, lateral view, ♂; *amph*, amphid; *oe*, esophagus; *nrv r*, nerve ring; *is*, isthmus; *oe blb*, esophageal bulb; *p ex*, excretory pore

there is probably no ampulla. The nerve ring is slightly anterior to the middle of the esophagus.

The protruding vulva can best be understood by reference to Figure 7, A. It is located slightly posterior to the middle of the body (not including the caudal spike). The female reproductive system is double. The vagina is divided near the middle into two portions, a comparatively thin-walled part joining the uteri and a heavy muscular part joining the vulva. The ova are ellipsoidal, 80μ by 60μ in diameter, and are deposited before segmentation.

Male:

0.61	13.	20.	'M	83.	1.45 mm.
0.43	6.0	7.00	8.0	3.0	

Body moderately robust, total length 1 to 1.4 mm.; diameter at middle of body, 58μ to 90μ; annulation coarse and fairly conspicuous, averaging 5μ to 7μ in width. Narrow alae are present, 4μ wide at middle of body. A head region is set off by a constriction somewhat wider and shallower than that in the female. The mouth opening is triangular and without distinct lips. The lobelike projections occurring on the head of the female could not be definitely seen on the male. It is not improbable that these projections do occur on the male; in fact, what may have been four, or even eight, very small elevations (fig. 8, B) were observed. The amphids are large and conspicuous, the elliptical external manifestations measuring about 4.5μ by 2μ. The vestibule wall is not so heavily cuticularized as in the female. The anterior portion of the esophagus (fig. 6, B) is expanded slightly in the middle, where it has a diameter about three-eighths that of the corresponding body diameter. It gradually tapers both anteriad and posteriad. The

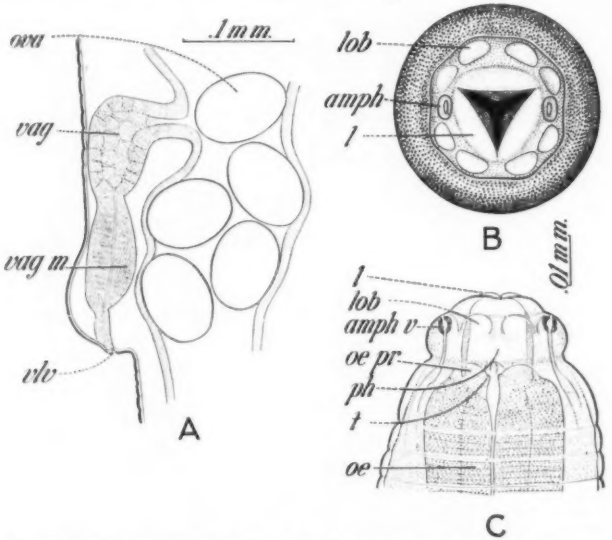

FIGURE 7.—*Thelastoma macramphidum:* A, Vulva and vagina, lateral view; *ova*, ova; *vag*, vagina; *vag m*, muscular portion of vagina; *vlv*, vulva; B, end view of head, ♀; *lob*, lobe; *amph* amphid; *l*, lip; C, dorsal view of head, ♀; *l*, lip; *lob*, lobe; *amph v*, amphidial vestibule; *oe pr*, esophageal projection; *ph*, pharynx; *t*, tooth; *oe*, esophagus

isthmus is a little longer than in the female, the cardiac bulb a little more elongated, and the excretory pore situated a little farther back. The nerve ring is but slightly anterior to the isthmus, being considerably farther back than in the female. The intestine is dilated anteriorly to form a ventriculus.

The shape of the tail of the male is shown in Figure 8, A and C. The anus is located on a distinct elevation and is surrounded by five (or possibly they should be considered as six) papillae; a pair of preanal papillae, one on the right side and one on the left, situated rather close together; a pair about opposite the anus separated a little farther from one another; and a median, postanal, duplex papilla. The two nerve endings present in this last-mentioned papilla indicate that it is really double, probably representing an anastomosed pair. A pair of papillae also occur on the tail about 80μ from the anus, i. e., just behind the beginning of the middle third. The length of the tail, however, is variable. Even in different individuals of approximately the same body size it may differ considerably. The preanal papillae are about 5μ long and 4μ wide, those opposite the anus and

those on the tail about the same size, possibly a little smaller. The latter are not always in the same transverse plane. The spicule (fig. 8, A) varies in length from 40μ to 55μ with a diameter of from 3.5μ to 5μ in its thickest region, which is about one-third the distance from its proximal end. It is slightly expanded at its proximal end, and ends distally in a ball-like enlargement a micron or more in diameter. The testis is large and reflexed.

Host.—Larva of Osmoderma (*O. scabra* Beauv.?).

Location.—Posterior end of intestine.

Locality.—Near Ann Arbor, Mich., U. S. A.

Type specimens.—United States National Museum Helminthological Collections No. 8110.

Paratypes.—No. 8111.

Technic.—Material killed in hot Flemming's strong, preserved in 4 per cent formalin, and cleared in glycerin. All observations and measurements made on specimens so treated.

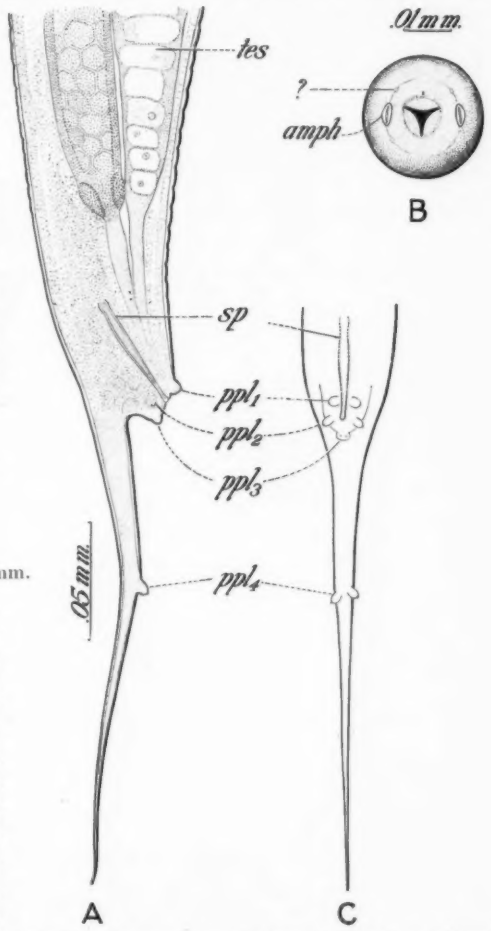

FIGURE 8.—*Thelastoma macramphidum:* A, Posterior end, lateral view, ♂; *tes*, testis; *sp*, spicule; ppl_1, preanal papillae; ppl_2, papillae opposite anus; ppl_3, median, postanal, duplex papilla; ppl_4, papillae on caudal spike; B, end view of head, ♂; (?), small elevations ?; *amph*, amphids; C, posterior end, ventral view, ♂; *sp*, spicule; ppl_1, preanal papillae; ppl_2, papillae opposite anus; ppl_3, median, duplex, postanal papilla; ppl_4, papillae on caudal spike

Thelastoma (Thelastoma) papilliferum, n. sp. (Figs. 9, 10, and 11.)

Female:

0.4 8.0 17. '46' 72.
0.8 4.0 5.6 6.7 4.0 3.9 mm.

Body moderately robust, total length 3.25 to 4.25 mm., diameter at middle of body 0.18μ to 0.28μ, caudal spike 0.45 to 0.9 mm. long from the anus. First annule back of the head 18μ wide, succeeding annules 7μ, increasing gradually to 12μ in middle of body. Alae are not present. Seen from in front the amphids appear oblong in shape, being about 3μ by 2μ. These measurements represent the outline of the vestibule seen under the cuticle, the opening being a broad slit about 1.5μ long. The head is rounded and set off by a wide constriction. The triangular mouth is bordered by three slightly arched lips (fig. 9, C), each lip being faintly divided into two parts. On the anterior outer margin of the head is a circle of eight elevations, distinctly innervated and in every respect papilloid in character. Each is about 4μ in height and slightly oblong in optical cross section at its base, with a greater diameter of 4μ. There extend into the base of the pharynx three comparatively large,

rather blunt, more or less toothlike projections. (Fig. 9, C.) The anterior portion of the esophagus is nearly cylindrical, and the isthmus is set off by a constriction and is but slightly reduced in diameter. The intestine is slightly dilated anteriorly.

The excretory pore is opposite the cardiac bulb. The nerve ring is located posteriad about three-fifths the distance from the pharynx to the isthmus.

The vulva (fig. 10) is located slightly posterior to the middle of the body (not including the terminal spike) and is set off by small lips, but does not protrude. The vagina is short and about 0.1 mm. in length, extends anteriad, and is divided

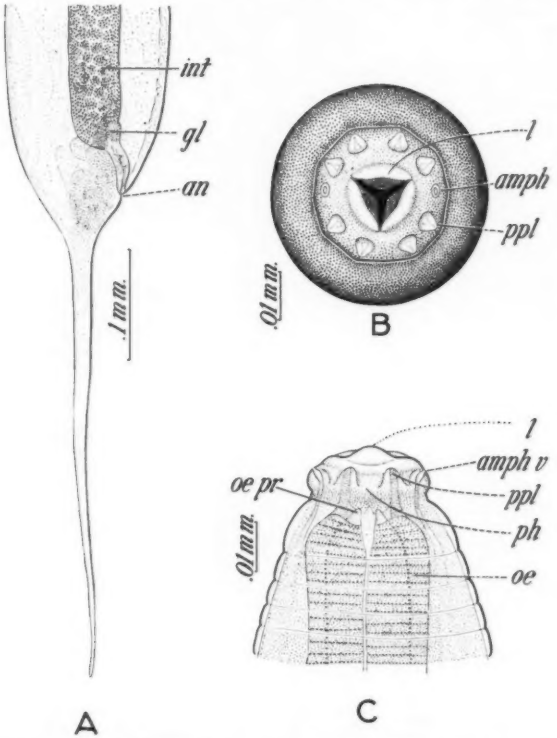

FIGURE 9.—*Thelastoma papilliferum:* A, Posterior end, lateral view, ♀; *int*, intestine; *gl*, gland; *an*, anus; B, end view of head, ♀; *l*, lip; *amph*, amphids; *ppl*, papillae; C, dorsal view of head, ♀; *oe pr*, esophageal projection; *l*, lip; *amph v*, amphidial vestibule; *ppl*, papillae; *ph*, pharynx; *oe*, esophagus

into two regions. That next to the uteri constitutes about two-thirds of the total length, has a diameter of 35μ, is thick-walled and not predominantly muscular. The remaining third has a diameter about half as great, a thick muscular wall, a narrow and more heavily cuticularized lumen, and is surrounded by a hemispherical mass of muscular tissue. On the right side of the vagina near the vulva and embedded in the surrounding tissue are five or six unicellular structures, 10μ to 15μ in diameter, which resemble glands. The reproductive system is double. The ova are ellipsoidal (80μ by 60μ) and are deposited before segmentation.

Male:

0.36	13	19	'M	80	1.12mm.
0.36	5.5	6.5	7.5	3.5	

Body moderately robust, total length 1 to 1.2 mm.; diameter in middle of body 60μ to 74μ, caudal spike 0.19 to 0.22 mm. long from anus. The head (fig. 4, B) is very faintly set off by a broad, almost imperceptible constriction, and adjacent to it there appears to be a wide annule, but the striae near the head are not distinct. The annules are 6μ wide near the middle of the body. Alae are present 4μ wide at the middle of the body. The amphids are relatively small, with the external manifestation elliptical. The eight papillalike structures characteristic of the female were not seen on the head of the male. The anterior portion of the esophagus (fig. 11, A) is nearly cylindrical throughout, and the isthmus is set off by a fairly distinct constriction. The cardiac bulb is broadly pyriform and the valvular apparatus relatively large and distinct. The intestine is dilated anteriorly to form a ventriculus.

The excretory pore is slightly posterior to the cardiac bulb, and the nerve ring is at the anterior end of the isthmus.

The anus is located on a distinct elevation, and there are five circumanal papillae: One pair slightly preanal and rather close together (fig. 11, B); one pair opposite the anus and somewhat more widely separated; and a single median, duplex, postanal papilla. The spicule is very faintly expanded at the proximal end and slightly expanded at the tip. The tail tapers gradually throughout its length and ends in a sharp point. Somewhat more than one-third the distance from the anus to the tip it bears a pair of papillae slightly larger than the preanal papillae, and at this point usually bends abruptly dorsad. The testis is large and reflexed.

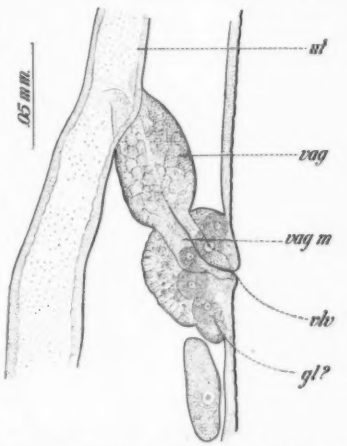

FIGURE 10.—*Thelastoma papilliferum*, vulva and vagina, lateral view; *ut*, uterus; *vag*, vagina; *vagm*, muscular portion of vagina, *vlv*, vulva; *gl?* gland?

Host.—Larva of Osmoderma (*O. scabra* Beauv.?).

Location.—Posterior end of intestine.

Locality.—Near Ann Arbor, Mich., U. S. A.

Type specimens.—United States National Museum Helminthological Collection No. 8112.

Paratypes.—No. 8113.

This species resembles *Thelastoma macramphidum*, but differs from it in the following respects: In the female the cephalic elevations are more papilloid in character and distinctly innervated, the amphids smaller with the amphidial vestibule less heavily cuticularized; and the vulva is situated a little farther forward and is not salient. In the male the amphids are considerably smaller, and the anal elevation somewhat more pronounced.

GENUS AORURUS LEIDY 1849

Aorurus subcloatus, n. sp. (Figs. 12, 13, and 14.)

Female:

0.16	1.7	9.0	'57'	58	3.05 mm.
0.85	2.3	5.3	4.0	2.6	

Body robust, total length 2.3 to 3.5 mm., caudal spike 1 to 1.2 mm. long from anus. Annulation coarse, very conspicuous; annules 10μ wide back of head region, increasing to 20μ at middle of body. Narrow alae are present. The head (fig. 12, A) is more or less truncate and very short. The circular to sub-

triangular mouth is not bordered by lips. The amphids are located on the outer anterior margin of the head. The conspicuous external manifestations (fig. 13, B) are elliptical, 3.5 by 2μ. This is likewise probably the outline of the vestibule below the cuticle, the openings being obscure. When seen in dorsoventral aspect, the vestibule (fig. 13, C) is 2μ wide by 3 to 3.5μ long, with a wall not heavily cuticularized. Surrounding the mouth, in a circle with the amphids, are eight slightly elevated, somewhat incurved lobes. When seen from in front these lobelike elevations are about 6μ broad and somewhat rectangular in outline. They were not observed to be innervated. The pharynx (fig. 13, C) is

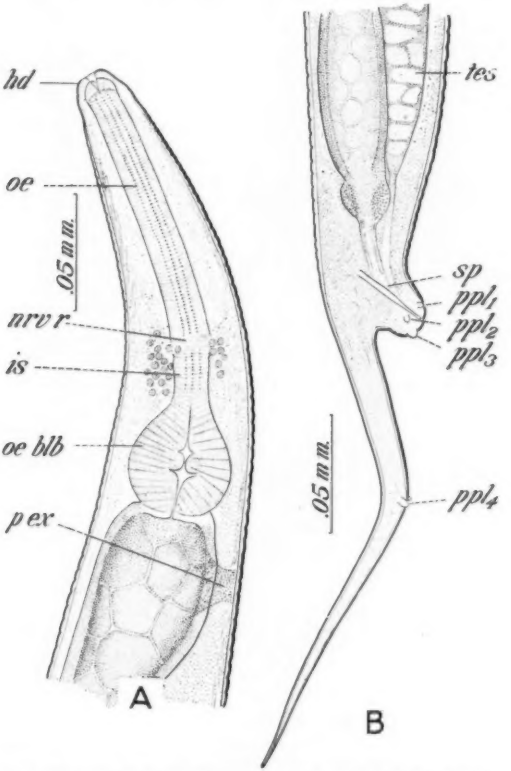

FIGURE 11.—*Thelastoma papilliferum:* A, Anterior end, lateral view, ♂; *hd*, head; *oe*, esophagus; *nrv r*, nerve ring; *is*, isthmus; *oe blb*, esophageal bulb; *p ex*, excretory pore; B, posterior end, lateral view, ♂, *tes*, testis; *sp*, spicule; ppl_1, papillae slightly preanal; ppl_2, papillae opposite anus; ppl_3, median, duplex, postanal papilla; ppl_4, papillae on caudal spike

about 5μ deep by 9μ wide, and unarmed. While the inner anterior margins of the three segments of the esophagus are somewhat angular, they are not toothlike.

The esophagus is short (0.22 mm.), and the anterior portion is enlarged into a distinct, pyriform median bulb (fig. 12, A), the diameter of which (70μ) is nearly as great as that of the cardiac bulb. The isthmus is short, distinct, and slightly expanded in the middle. The cardiac bulb is broadly pyriform and rather dense with granular material. It opens posteriad through a slightly projecting cardia into the large ventriculus. The latter has a maximum diameter four-fifths as great as the corresponding body diameter and tapers gradually posteriad. The posterior end of the intestine is not dilated.

The rectum (fig. 14) is conoid, has a length a little greater than the anal body diameter, and possesses a narrow cuticularized lumen. While rectal glands were not seen and consequently not figured, they are very likely present. The tail averages 1 mm. in length, or over 30 per cent of the total body length. It is 7μ to 8μ in diameter where it joins the body and tapers gradually to a fine point.

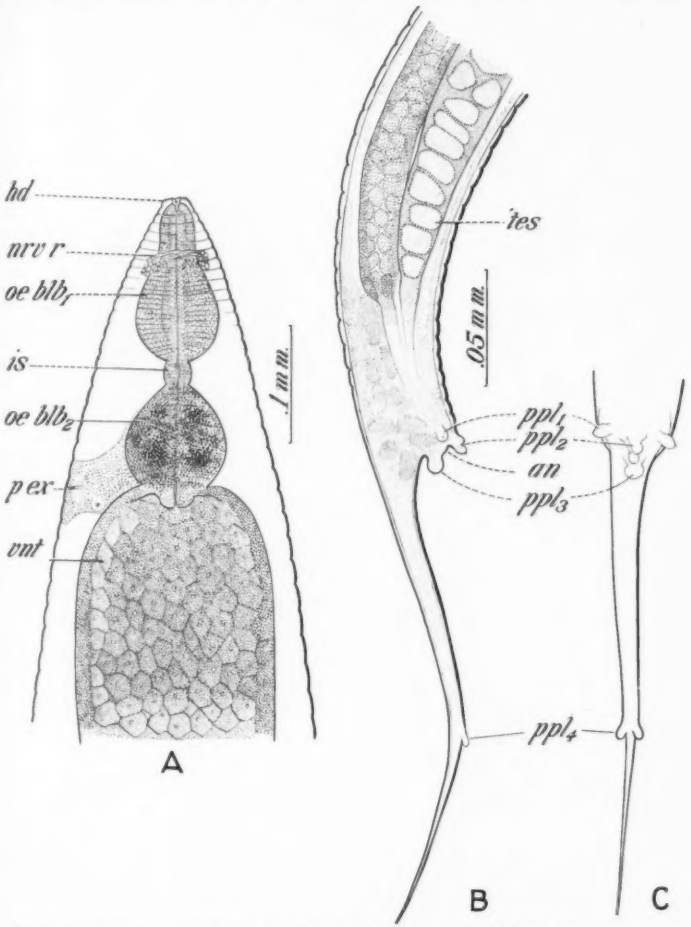

FIGURE 12.—*Aorurus subcloatus:* A, Anterior end, lateral view, ♀; *hd*, head; *nrv r*, nerve ring; *oe blb*$_1$, median bulb; *oe blb*$_2$, cardiac bulb; *is*, isthmus; *p ex*, excretory pore; *vnt*, ventriculus; B, posterior end, lateral view, ♂; *tes*, testis; *ppl*$_1$, papillae on sides of anal elevation; *ppl*$_2$, submedian, preanal papillae; *ppl*$_3$, median, duplex, postanal papilla; *ppl*$_4$, papillae on caudal spike; *an*, anus; C, posterior end, ventral view, ♂ (legends as in B)

The nerve ring (fig. 12, A) encircles the neck of the median bulb. The excretory pore is opposite the cardiac bulb.

Measured on the outer contour of the body, the vulva (fig. 14) is located about 30μ anterior to the anus and is slightly salient. The vagina extends anteriad about one-third the distance from the anus to the head, where it branches to form the two uteri. The posterior end for a distance of 90μ is differentiated into

a muscular-walled region with a narrow lumen, while the remainder is a thin-walled tube with a wide lumen. The organization of the remainder of the female reproductive system is very similar to that in all the other species dealt with in this paper. The shifting of the vulva posteriad does not materially affect the position of the uteri and ovaries.

The ellipsoidal ova, 90μ long by 60μ broad, are not noticeably flattened on one side, and are deposited before segmentation begins.

Male:

0.74	13	19.	'M	80.	1.08 mm.
0.76	5.0	5.3	5.3	3.5	

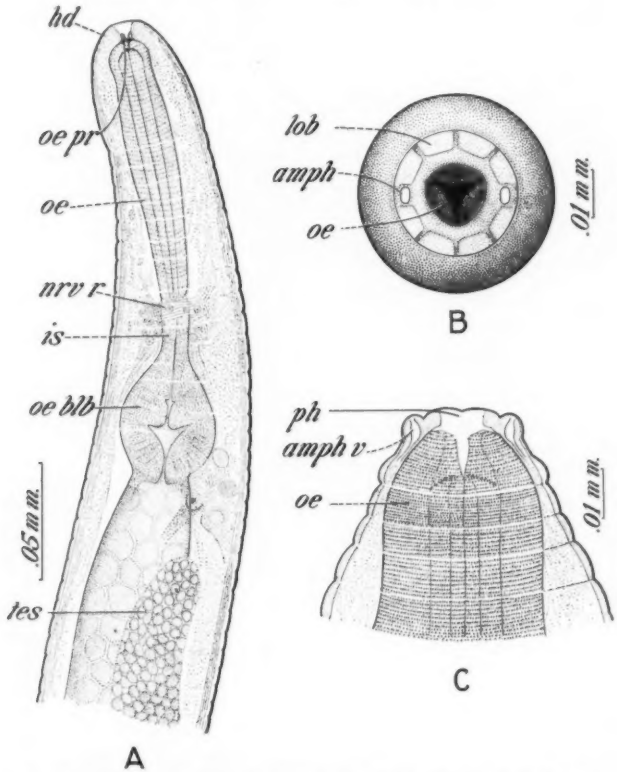

FIGURE 13.—*Aorurus subcloatus:* A, Anterior end, lateral view, ♂; *hd*, head; *oe pr*, esophageal projections; *oe*, esophagus; *nrvr*, nerve ring; *is*, isthmus; *oe blb*, esophageal bulb; *tes*, testis; B, end view of head, ♀; *lob*, lobe; *amph*, amphid; *oe*, esophagus; C, dorsal view of head, ♀; *ph*, pharynx; *amph v*, amphidial vestibule; *oe*, esophagus

Body moderately slender, total length 0.84 to 1.1 mm., caudal spike 0.15 to 0.18 mm. long. Annulation coarse and conspicuous, annules 5μ wide back of headcap, increasing to 6μ or 8μ in middle of body. Narrow alae present, 6μ wide in middle of body. The head (fig. 13, A) is rounded, and lacks the lobelike elevations of the female. The amphids are similar in shape to those of the femlae, but smaller and less conspicuous. The mouth is subtriangular and not bordered by lips. Posteriad from the mouth for a distance of 50μ the anterior end lacks transverse striae, forming a smooth, slightly expanded headcap. (Fig. 13, A.) The pharynx is 8μ deep with an average diameter of 6μ. There protrudes into it from each of the three sectors of the anterior end of the esophagus a small, somewhat toothlike projection.

The anterior portion of the esophagus expands gradually posteriad to a point opposite the posterior margin of the headcap, where its diameter is 22μ to 25μ, then gradually diminishes in size until, adjacent to the isthmus, its diameter (14μ to 18μ) is less than at the anterior end. While it is thus noticeably expanded, it does not possess any suggestion of a median bulb. The isthmus is set off anteriorly by a distinct constriction, is about 28μ long, and has a diameter of from 12μ to 14μ. The cardiac bulb is slightly longer than broad and possesses a very large and conspicuous valvular apparatus. The intestine may be somewhat dilated anteriorly.

The excretory pore is slightly posterior to the cardiac bulb; the nerve ring is at the anterior end of the isthmus.

The anus (fig. 12, B) is located on an elevation, and is surrounded by five circumanal papillae. There is a median pair of preanal papillae (fig. 12, B and C), more or less joined at their base and in many specimens so arranged as to appear one behind the other. There is also a pair (one right and one left) of more widely separated, somewhat preanal papillae occurring on the sides of the anal elevation, and a median, duplex, postanal papilla with two nerve endings. Another pair occurs on the tail about three-fifths the distance from the anus to the tip. All the papillae are somewhat larger than those of *Thelastoma macramphidum*. The four preanal papillae are 8μ long and 5.5μ to 6μ wide, while the postanal papilla is about 8μ long and 8μ wide when seen in dorsoventral aspect. *Host.*—Larva of Osmoderma (*O. scabra* Beauv.?).

Location.—Posterior end of intestine.

Locality.—Near Ann Arbor, Mich., U. S. A.

Type specimens.—United States National Museum Helminthological Collections No. 8114.

Paratypes.—No. 8115.

Technic.—Material killed in warm Flemming's strong, preserved in 4 per cent formalin, and cleared in glycerin. All observations and measurements were made on specimens so treated.

FIGURE 14.—*Aorurus subcloatus*, posterior end, lateral view, ♀; *vag m*, muscular portion of vagina; *vlv*, vulva; *an*, anus; *vag*, vagina; *ov*, ovary; *int*, intestine; *rct*, rectum

The females of this species resemble those of *Aorurus agile* Leidy, 1849, but are at once distinguished from them by the close proximity of the vulva to the anus.

The papillae on the tail of the male are situated considerably farther back than the corresponding papillae on the tail of *Thelastoma macramphidum* or *T. papilliferum*. A very distinct cuticularization was noted near the anus, which may have been a rudimentary spicule or the wall of the cloaca. In several cases a very small, indistinct projection was noted protruding from what appeared to be the lip posterior to the anus or possibly through the anus itself. Whether or not this was connected with the cuticularization within could not be determined from the specimens available. In dorsoventral view this projection was obscured by the preanal papillae.

SUMMARY

Four new oxyurid parasites of scarabaeid larvae are described. One species from an unidentified scarabaeid larva belonging either to the Rutelinae or the Melolanthinae is placed in a new genus, Scarabanema. Two new oxyurid parasites from the larva of a species of Osomoderma (*O. scabra* Beauv.?) are placed in the genus Thelastoma Leidy, and one new species from the same host is placed in the genus Aorurus Leidy. Keys to the genera and species are given.

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GROWTH HABIT AND YIELD IN WHEAT AS INFLUENCED BY TIME OF SEEDING [1]

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INTRODUCTION

Almost the entire wheat crop of eastern Oregon was destroyed by freezing in December, 1924. A preliminary date-of-seeding experiment conducted at the Sherman County branch station, Moro, Oreg., during 1923–24 had shown that winter wheat could be sown as late as February 15 and still head and produce yields equal to or better than those of spring varieties. Farmers were advised of this fact, and many of them took advantage of favorable weather in late January and early February, 1925, and reseeded their land to winter varieties, with good results. The experiments were enlarged and continued to obtain more complete data as to the latest date at which winter varieties could be sown and still yield as well as spring varieties, or even produce heads and seed.

REVIEW OF LITERATURE

Aamodt (*1*)[4] states that Kanred winter wheat sown in the spring at St. Paul, Minn., produced an occasional head late in the season but did not set seed. Gaines (*8*) found that winter barley tillered profusely but did not head when spring sown at Pullman, Wash. Schafer et al. (*14*) reported that Hybrid 128 winter wheat sown after March 11 would not head until the second season. Call and Salmon (*4*) reported that wheat sown in Kansas in February produced a fair yield in some cases. Seiger,[5] a farmer at Malin in Klamath County, Oreg., obtained a yield of 36 bushels per acre from Turkey wheat sown March 15, whereas the same variety sown April 10 did not head. This was at an altitude of about 4,500 feet where the growing season is short. Breithaupt (*3*) states that winter rye sown in south central Oregon as late as April 1 may produce fair yields, although a delay of one or two weeks in the time of seeding may result in failure.

Percival (*13*), in England, found that all winter-wheat varieties sown before the end of March produced ears the same season, but that after this period there is a critical date for each variety. If sown after this critical date, the plants of any winter variety continue prostrate vegetative growth during the summer and head during the second year, if not killed by drought or other unfavorable conditions. Percival found that a given variety sown on the same date headed on nearly the same date each year. Different varieties sown on each of several dates maintained relative heading dates.

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[3] Assistant in the cooperative experiments at the Sherman County branch station, Moro, Oreg.

[4] Reference is made by number (italic) to Literature Cited, p. 499.

[5] SEIGER. [WHEAT LETTER FROM MALIN, OREG.] Letter on file in Farm Crops Dept., Oregon Agr. Col. 1924.

Adams (*2*) seeded Kharkof winter wheat and winter rye in pots in the greenhouse at Ottawa, Canada, at weekly intervals from March 5 to April 23, 1923. The plants were transplanted outside May 15. All plants sown in March headed out and completed their life cycle the same season. Plants sown in April in most cases did not produce heads until the next season, when they headed normally. With rye the difference in growth from the different dates of seeding was not marked. A few heads were produced from each date of seeding except one in 1923, but plants from each date of seeding lived over and produced heads in 1924.

Kiesselbach (*12*) sowed Nebraska 60, a strain of Turkey wheat, at Lincoln, Nebr., on different dates from September to late March in the years 1919 to 1923, inclusive. No heads were produced from the crop sown March 4 to 26 in four of the years, and only a half bushel of grain per acre in the fifth year. The crop sown March 2 to 11 in the same years produced no grain in two of the years and an average of 9.1 bushels for the other three years. The crop sown from January 25 to February 18 produced grain each year, averaging 11.8 bushels. Sowings made September 20 to 25 averaged 34.2 bushels per acre.

Garner and Allard (*9*) found that by varying the daily exposure to light through the use of electric lights in the greenhouse many plants of different species could be made to flower and produce seed at any period of the year. They suggested that length of day and not temperature determines the time when flowering will occur. They divided plants into two groups, "short day" plants, which flower and fruit as the days grow shorter, and "long day" plants, which flower and fruit as days grow longer. They placed the cereals in the "long day" group.

Following up the work of Garner and Allard, Wanser (*16, p. 314*) suggested that one ratio of daylight to darkness may cause a variety of wheat to joint and another ratio may cause it to head. He suggested that the photoperiods causing jointing in spring-wheat varieties are of greater magnitude than for winter varieties and possibly without a maximum limit. To quote: "Photoperiodism, therefore, is the key to the distinction between winter and spring wheats." He also suggested that the northern limit of the winter-wheat belt is controlled largely by the relation between the date when active growth begins and the date on which the longest day within the limit of the critical photoperiod for jointing occurs. Cooper (*5*) states that winter wheat will not head when sown in the spring, because it requires a long vegetative period, and by the time this is over the duration of daily sunlight is too short to bring the plants into heading. Artificial light greatly reduced the growing period of wheat sown early in the greenhouse. There was little effect, however, on wheat sown as late as the middle of February, because the artificial light had less effect as the days became longer in the spring.

It was once supposed that winter varieties of the cereal crops must pass through a period of low temperature after germination before they could head. Recent experiments have shown that a freezing temperature is not necessary. Fruwirth (*7*) states that in true winter varieties no stalks will ripen, or at most only a few, if the seed is sown in March or later. If the plants from later sown seed are exposed for a sufficient length of time to temperatures lower than

the ones to which the older plants are subjected they will produce heads and will ripen. They need not be exposed to frost, however. Call and Salmon (*4*) state that after winter wheat has germinated it must pass through a cool period but not a freezing one before it will head.

Hutcheson and Quantz (*11*) grew winter varieties of wheat, oats, barley, and rye in greenhouses kept at 75°, 65°, 62°, and 58° F. Wheat showed striking differences in growth as a result of variation in temperature, producing a normal growth in the cool house but only a mass of leaves in the two warmest houses.

Gassner (*10*) germinated seeds of winter and spring varieties of rye, wheat, and barley at 1°–2°, 5°–6°, 12°, and 24° C. on each of several dates and then set the plants outdoors under uniform conditions. All plants of spring varieties, from seeds germinating at the same time, even under different temperatures, headed at the same time. Plants of winter varieties from seeds germinated at the lower temperatures headed sooner. Thus, plants from seeds germinated during the middle of March at 1°–2° C. formed heads 9, 21, and 41 days earlier, respectively, than the plants from seeds germinated at the same time but at 5°–6°, 12°, and 24° C. The later the date of seeding the lower was the temperature required at germination for winter varieties to head. Gassner believed that low temperature had a positive effect even when limited to the germination phase, and that winter wheat, rye, and barley will produce grain when spring sown if subjected to a sufficiently low temperature during germination.

Dickson (*6*) grew Turkey wheat (Wisconsin Pedigree No. 2) in the greenhouse from October until the following summer in soils in which temperatures varied at 4° intervals from 8° to 36° C. The plants grown in soil held at temperatures of 24° C. and higher produced an excessive vegetative growth with little or no formation of heads. When grown in soils held at temperatures of 20° C. and lower the plants headed normally during May. Chemical analyses showed that the plants grown at low temperatures were high in total carbohydrates and low in total nitrogen, whereas the reverse was true at higher temperatures. Strains of Turkey and White Winter wheat were grown to the first-leaf stage in the greenhouse at 5° C. and then transplanted to the field in April. Seed from the same strains was sown in the field at the same time. Of the Turkey plants grown from seed germinated in the greenhouse at 5° C., 62 per cent headed and formed grain. The Turkey plants grown from seed sown in the field made an excessive vegetative growth, but formed no heads. Among 12 varieties seed of which was germinated at 5° C. and transplanted to the field in April, all gradations in heading occurred. No heads were formed in some varieties, whereas in others 96 per cent of the plants formed heads. Dickson also found chemical differences in plants at the time of emergence when they were germinated at different temperatures, there being a decline in carbohydrates and an increase in total nitrogen when the seeds were germinated at higher temperatures. Wheat plants showed the effect of the germinating temperatures in the growth subsequent to the seedling stage even when this growth was made under uniform conditions.

Walster (*15*) planted Oderbrucker barley in pots on March 1. Part of the pots were kept at 15° and part at 20° C. He varied the nitrogen, phosphorus, and potassium in the nutrient solution added

to the pots. All plants grown at the low temperature headed normally, but only those receiving a low supply of nitrogen headed in the warmer houses. He believed a low carbohydrate-nitrogen ratio in the plant tissues turned the plants toward vegetative growth.

VARIETIES AND SOWING DATES

The experiments reported herein were conducted at Moro, Oreg., in the years 1925, 1926, and 1927. Thirteen varieties of wheat were sown in 1925 on several dates, ranging from February 2 to April 23; 16 varieties the following year, ranging from October 14, 1925, to June 4, 1926; and 8 in the third year, ranging from October 20, 1926, to May 31, 1927. The intervals varied from one to two weeks from February 1 to May 1, the period during which critical dates for the winter varieties occurred, but were longer during the early part of the winter. Varieties were chosen which represented a wide range of type. They included 11 typical winter varieties, 3 typical spring varieties, and 6 which may be classed as intermediate. A supplementary test including Marquis, Hard Federation, Quality, and Sunset was sown on July 6, 1927. Yields were not obtained on this seeding, as the varieties were injured by stock. Each variety was sown in two 3-row plots 1 rod long on each date. A brief description of each variety grown is given in Table 1.

TABLE 1.—*Description of the wheat varieties studied*

Variety	C. I. No.[a]	Head type[b]	Species	Grain color	Growth habit
Kharkof	8249	BSW	Triticum vulgare	Red	Winter.
Oro	8220	BSW	do	do	Do.
Regal	7364	BSW	do	do	Do.
Kanred	5146	BSW	do	do	Do.
Blackhull	6251	BSW	do	do	Do.
Turkey	7366	BSW	do	do	Do.
Ridit	6703	ASW	do	do	Do.
Triplet	5408	APW	do	do	Do.
White Odessa	4655	ASR	do	White	Do.
Fortyfold	4156	ASR	do	do	Do.
Hybrid 128	4512	ASW	Triticum compactum	do	Do.
Hybrid 63		ASW	do	do	Intermediate.
Hybrid 143	4513	ASW	do	do	Do.
Federation	4734	ASR	Triticum vulgare	do	Do.
Pacific Bluestem	4067	ASW	do	do	Do.
Jenkin		ASR	Triticum compactum	do	Spring.
Galgalos 39		APR	Triticum vulgare	do	Do.
Marquis	4158	ASW	do	Red	Do.
Baart	1697	BSW	do	White	Do.
Hard Federation	4733	ASR	do	do	Do.
Quality	6607	ASW	do	do	Do.
Sunset	3728	ASW	do	do	Do.

[a] Accession number of the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

[b] B=bearded, A=awnless, S=smooth chaff, P=pubescent chaff, W=white chaff, R=red chaff.

CLIMATIC CONDITIONS

Winterkilling of ordinarily hardy winter wheat is slight at Moro, and the temperatures usually are such that wheat will germinate if sown at any time during the winter. Good yields often are obtained from winter seeding.

The crop year of 1925 in eastern Oregon was unusual. Almost the entire wheat crop was killed in December, 1924, but temperatures were above normal after the middle of January, permitting seeding in late January and February. No winterkilling, even of tender spring varieties, occurred in 1925–26. Temperatures were above

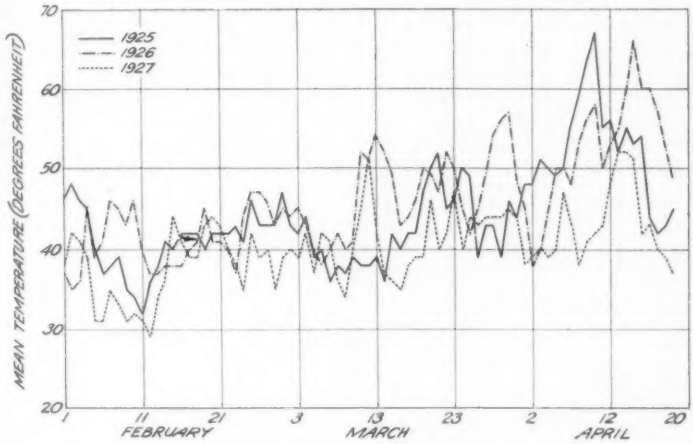

FIGURE 1.—Mean daily temperature, February 1 to April 20, in the years 1925, 1926, and 1927, at Moro, Oreg.

normal all during the winter. All varieties matured unusually early. No killing of winter varieties occurred in 1927, but some spring varieties sown October 20 were injured. These varieties sown on this date headed later than when sown during the late winter. The spring of 1927 was very late and cool, and the precipitation was above normal.

The maximum, minimum, and mean air temperatures, with departures from normal, number of clear days, and precipitation for the three crop years are given by months in Table 2. Figure 1 shows the mean daily temperature from February 1 to April 20 for each year.

TABLE 2.—*Maximum, minimum, and mean air temperatures with departures from normal, precipitation, and number of clear and partly clear days by months at Moro, Oreg., during the crop years 1925, 1926, and 1927*

Month	1924–25						1925–26						1926–27					
	Air temperature				Precipitation	Clear or partly clear days	Air temperature				Precipitation	Clear or partly clear days	Air temperature				Precipitation	Clear or partly clear days
	Maximum	Minimum	Mean	Departure of mean from normal			Maximum	Minimum	Mean	Departure of mean from normal			Maximum	Minimum	Mean	Departure of mean from normal		
	°F.	°F.	°F.	°F.	*Inches*	*Number*	°F.	°F.	°F.	°F.	*Inches*	*Number*	°F.	°F.	°F.	°F.	*Inches*	*Number*
September	94	33	59.8	+2.8	0.67	20	90	36	60.1	+2.9	0.55	16	84	21	55.3	−1.7	0.51	22
October	75	30	49.4	+0.4	.01	15	80	29	50.9	+1.8	.54	18	74	28	50.7	+1.4	1.12	20
November	52	21	36.5	−1.7	2.40	7	56	20	38.6	+0.3	.98	12	59	25	39.8	+1.2	4.24	13
December	59	−11	24.0	−6.3	1.17	13	56	25	37.0	+6.6	1.63	5	57	−6	31.1	+0.4	1.05	22
January	56	26	38.0	+7.7	1.53	7	52	22	33.0	+2.5	1.35	5	47	−15	26.6	−3.6	2.19	12
February	57	28	40.6	+6.6	1.80	9	61	26	41.0	+6.7	1.97	10	53	24	37.1	+2.6	2.40	16
March	68	22	42.1	+1.0	.45	11	71	25	46.7	+5.2	.10	26	60	23	43.7	+2.1	1.01	19
April	81	27	50.4	+3.2	.77	15	89	29	53.8	+6.2	1.07	19	80	21	46.5	−1.0	.07	21
May	80	33	57.2	+3.3	2.15	18	83	30	54.3	+0.4	.61	18	81	32	51.7	−2.0	.72	16
June	101	33	62.5	+1.2	.19	24	101	38	67.0	+5.3	.18	27	88	40	62.0	+0.3	.80	17
July	100	47	72.1	+4.0	T.	30	105	45	71.0	+2.7	.00	30	101	42	68.8	+0.5	.00	30
August	93	40	65.3	+2.0	.02	24	99	45	67.5	+0.2	.54	23	94	42	67.9	+0.6	.11	22

EXPERIMENTAL DATA

The dates of first and full heading, the height of the plants, yield in bushels, and weight per bushel of the varieties from each date of seeding in 1925 are shown in Table 3, for 1926 in Table 4, and for 1927 in Table 5. The varieties Hybrid 128, Kharkof, Kanred, Federation, Marquis, and Hard Federation constitute a more or less continuous series from the extreme winter type (Hybrid 128) to the early spring type (Hard Federation). Since the response of other varieties included in the experiment was similar to one or the other of these six, discussion will be limited to them.

TABLE 3.—*Dates first and fully headed, plant height, yield, and bushel weight of 13 varieties of wheat seeded in nursery rows at intervals during the season of 1924–25 at Moro, Oreg.*

Item and variety	C. I. No.	Date sown (first) and date emerged[a] (second)							
		Feb. 2 Mar. 19	Feb. 16 Mar. 20	Feb. 26 Mar. 24	Mar. 10 Mar. 31	Mar. 20 Apr. 5	Apr. 2 Apr. 12	Apr. 13 Apr. 27	Apr. 23 May 2
Date first headed:									
Hybrid 128	4512	June 15	June 19	June 23	(b)	(b)	(b)	(b)	(b)
Kharkof	8249	June 11	June 16	June 19	June 24	June 23	July 3	(b)	(b)
Kanred	5146	do	June 15	June 17	June 23	do	June 30	(b)	(b)
Turkey	7366	do	June 14	June 16	June 20	June 26	do	July 9	(b)
Pacific Bluestem	4067	May 31	June 5	June 7	June 12	June 18	June 23	June 27	July 6
Federation	4734	May 26	May 26	May 28	June 2	June 10	June 19	June 22	June 28
Hybrid 143	4513	June 7	June 12	June 16	June 20	June 21	June 26	July 2	July 9
Hybrid 63		June 12	June 15	June 17	do	June 23	do	July 1	Do.
Jenkin		June 13	do	do	do	June 21	June 25	do	July 7
Marquis	4158		June 7	June 7	June 11	June 16	June 18	June 22	June 24
Galgalos 39		June 2	June 6	do	do	June 15	June 19	do	June 27
Baart	1697			May 27	June 2	June 9	June 16	June 20	June 22
Hard Federation	4733			May 21	May 25	May 28	June 5	June 15	June 20
Date fully headed:									
Hybrid 128	4512	June 24	June 28						
Kharkof	8249	June 23	June 25	June 28					
Kanred	5146	do	do	June 26	July 1				
Turkey	7366	June 22	June 23	June 24	June 27	July 2			
Pacific Bluestem	4067	June 13	June 12	June 17	June 22	June 25	July 1	July 10	
Federation	4734	June 8	June 6	June 9	June 12	June 21	June 28	July 1	July 16
Hybrid 143	4513	June 18	June 21	June 23	June 27	June 30	July 6		
Hybrid 63		June 19	June 23	June 24	do	July 2	do		
Jenkin		June 21	do	do	do	June 29	July 4		
Marquis	4158		June 13	June 17	June 21	June 22	June 25	June 30	July 2
Galgalos 39		June 13	June 12	do	do	do	June 27	July 1	July 7
Baart	1697			June 8	June 11	June 20	June 23	June 29	July 2
Hard Federation	4733			May 28	June 2	June 8	June 18	June 22	June 27
Plant height (inches):									
Hybrid 128	4512	36	28	14					
Kharkof	8249	35	32	30	26	17	13		
Kanred	5146	33	31	31	27	19	14		
Turkey	7366	36	33	30	27	22	14	14	
Pacific Bluestem	4067	44	40	39	39	34	32	26	19
Hybrid 143	4513	36	32	31	30	26	22	19	17
Federation	4734	37	36	33	35	33	29	24	19
Hybrid 63		35	29	28	27	22	21	19	17
Jenkin		58	33	32	31	30	28	23	21
Marquis	4158		36	37	37	34	32	27	27
Galgalos 39		38	35	36	34	33	28	24	23

Baart	1697			36	39	37	35	29	27
Hard Federation	4733			31	33	32	31	27	24
Bushels per acre:									
Hybrid 128	4512	26.8	24.8	8.1	0	0	0	0	0
Kharkof	8249	20.2	16.9	22.2	16.1	6.8	1.7	0	0
Kanred	5146	16.6	20.3	18.5	22.4	9.6	3.8	0.7	0
Turkey	7366	15.9	14.4	19.3	19.2	17.3	6.5	2.2	0
Pacific Bluestem	4067	19.6	18.4	21.5	21.8	21.8	15.1	9.9	13.7
Federation	4734	19.6	24.2	23.5	22.5	21.7	17.1	16.2	13.9
Hybrid 143	4513	25.7	22.1	22.2	21.0	18.2	13.9	8.5	11.1
Hybrid 63		24.2	22.5	22.0	23.7	22.7	18.8	11.5	12.4
Jenkin		23.6	22.4	22.3	20.1	19.1	17.8	12.3	15.0
Marquis	4158		19.3	21.2	19.6	17.3	15.0	10.7	15.2
Galgalos 39		19.2	14.2	15.1	18.1	23.8	18.6	14.1	13.4
Baart	1697			18.4	17.5	18.2	16.4	14.4	16.4
Hard Federation	4733			22.1	22.3	19.3	17.7	17.2	19.8
Weight per bushel (pounds):									
Hybrid 128	4512	56.8	56.5						
Kharkof	8249	55.7	55.8	57.0	57.7				
Kanred	5146	55.0	54.4	54.6	56.1				
Turkey	7366	52.0	51.4	51.9	53.1	55.6			
Pacific Bluestem	4067	53.5	52.5	54.0	53.0	54.1	53.0	51.0	54.5
Federation	4734	52.3	50.0	51.0	50.7	51.7	52.0	51.1	52.9
Hybrid 143	4513	58.5	57.0	57.0	55.7	57.0	54.3	55.0	56.5
Hybrid 63		57.2	58.2	57.9	58.1	60.5	57.0	55.5	59.3
Jenkin		54.2	53.0	54.9	54.0	54.5	51.2	51.6	54.0
Marquis	4158		54.0	54.4	53.4	54.0	52.2	49.0	50.1
Galgalos 39		56.5	50.2	51.0	51.2	53.4	52.0	51.0	54.0
Baart	1697			53.0	52.2	54.0	51.9	51.5	51.5
Hard Federation	4733			55.0	54.0	51.6	52.1	51.6	53.0

[a] The emergence dates may have varied 1 or 2 days from the averages given.

[b] None or only a very few green heads Sept. 10.

TABLE 4.—*Dates first and fully headed, plant height, yield, and bushel weight of 16 varieties of wheat seeded in nursery rows at intervals during the season of 1925–26 at Moro, Oreg.*

Item and variety	C. I. No.	Date sown (first) and date emerged [a] (second)													
		Oct. 14 Oct. 26	Nov. 13 [b]	Dec. 17 Feb. 14	Jan. 25 [b]	Feb. 8 Mar. 12	Feb. 15 Mar. 13	Feb. 22 Mar. 18	Mar. 1 Mar. 20	Mar. 6 Mar. 22	Mar. 18 Mar. 30	Apr. 3 Apr. 12	Apr. 16 Apr. 24	Apr. 30 May 8	May 21 May 27	June 4 June 11
Date first headed:																
Hybrid 128	4512	May 14	May 26	June 2	June 6	June 12	June 23	July 6	(c)	(c)	(c)	(c)	(c)	(c)	(c)	(c)
Kharkof	8249	May 15	May 23	May 31	June 3	June 6	June 9	June 16	June 22	June 25	(c)	(c)	(c)	(c)	(c)	(c)
Oro	8220	do				do	June 11	June 17	June 23	do	(c)	(c)	(c)	(c)	(c)	(c)
Ridit	6703	May 13				do	do	June 24	June 25	July 6	(c)	(c)	(c)	(c)	(c)	(c)
White Odessa	4655	May 18	June 1	June 6	June 10	June 13	June 17	do	June 28	July 8	(c)	(c)	(c)	(c)	(c)	(c)
Fortyfold	4156	May 12				June 6	June 8	June 21	June 20	do	(c)	(c)	(c)	(c)	(c)	(c)
Triplet	5408	May 13				June 4	June 7	June 14	June 24	June 26	(c)	(c)	(c)	(c)	(c)	(c)
Regal	7364	May 14				June 6	June 8	do	June 17	June 23	(c)	(c)	(c)	(c)	(c)	(c)
Kanred	5146	May 16	May 23	May 31	June 3	do	June 7	June 9	June 12	June 25	June 23	July 1	(c)	(c)	(c)	(c)
Blackhull	6251	May 12	May 15	May 22	May 30	May 31	June 4	June 6	June 7	June 11	June 21	do	(c)	(c)	(c)	(c)
Turkey	7366	May 14	May 22	May 26	June 3	June 4	June 6	June 8	June 11	June 13	June 20	June 28	(c)	(c)	(c)	(c)
Pacific Bluestem	4067	May 10	May 17	May 22	May 28	May 31	June 2	June 3	June 4	June 5	June 10	June 20	June 27	July 7	(c)	(c)
Federation	4734	May 1	May 11	May 13	May 17	May 21	May 24	May 25	May 26	May 29	June 3	June 11	June 23	July 3	(c)	(c)
Hybrid 63		May 14	May 23	May 29	June 3	June 5	June 5	June 6	June 7	June 8	June 10	June 21	June 26	July 7	July 30	(c)
Marquis	4158		May 20	May 26	May 21	June 2	June 3	June 3	June 4	June 4	June 6	June 11	June 17	June 27	July 11	July 31 [d]
Hard Federation	4733		May 4	May 10	May 12	May 14	May 16	May 17	May 18	May 19	May 23	June 2	June 8	June 19	July 7	July 18 [d]
Date fully headed:																
Hybrid 128	4512	May 27	June 4	June 8	June 17	June 26										
Kharkof	8249	May 28	June 2	June 9	June 15	June 16	June 24									
Oro	8220	do				do	June 25	July 3								
Ridit	6703	May 22				June 15	June 24	July 10								
White Odessa	4655	May 28	June 9	June 16	June 23	June 25	June 26									
Fortyfold	4156	May 22				June 16	June 18	July 10								
Triplet	5408	do				June 11	June 17	July 2								
Regal	7364	May 29				June 15	June 22	July 1								
Kanred	5146	do	June 2	June 9	June 15	June 16	June 20	June 24	June 27							
Blackhull	6251	May 22	May 26	June 2	June 7	June 8	June 12	June 15	June 18	June 25						
Turkey	7366	May 25	June 1	June 8	June 15	June 12	June 15	June 18	June 24	June 27						
Pacific Bluestem	4067	May 20	May 28	June 1	June 6	June 7	June 8	June 10	June 12	June 16	June 24		July 15			
Federation	4734	May 14	May 19	May 23	May 28	June 1	June 3	June 3	June 4	June 6	June 12	July 4	do			
Hybrid 63		May 27	June 2	June 6	June 15	June 15	June 15	June 16	June 18	June 24	June 25	July 10	do			
Marquis	4158		May 31	June 4	June 6	June 8	June 9	June 10	June 12	June 12	June 15	June 23	June 25	July 7	July 23	
Hard Federation	4733		May 14	May 19	May 21	May 23	May 25	May 26	May 27	May 30	June 2	June 11	June 16	July 3	July 24	
Plant height (inches):																
Hybrid 128	4512	35	33	33	29	23	18	16								
Kharkof	8249	35	33	34	32	29	30	18	21	19						
Oro	8220	35				30	31	21	19	14						
Ridit	6703	38				29	29	21	16	18						
White Odessa	4655	38	34	33	33	30	29	19	19	15						

Fortyfold	4156	36				32	30	20	18	16						
Triplet	5408	33				28	29	19	20	18						
Regal	7364	33				29	31	23	21	20						
Kanred	5146	32	34	35	30	31	31	24	25	19	18	18				
Blackhull	6251	35	38	36	32	32	33	29	28	27	21	17				
Turkey	7366	31	36	36	30	30	31	25	27	23	19	15				
Pacific Bluestem	4067	38	37	37	36	34	34	34	33	35	26	23	22	18		
Federation	4734	36	33	34	34	33	34	34	35	32	26	23	20	19		
Hybrid 63		35	29	32	29	24	26	26	23	22	23	19	22	17	13	
Marquis	4158		36	36	35	36	32	34	29	31	27	27	27	24	18	
Hard Federation	4733		33	34	36	34	33	32	34	31	28	25	24	22	13	13
Bushels per acre:																
Hybrid 128	4512	25.4	24.3	27.0	24.1	17.9	11.2	0.9	0	0	0	0	0	0	0	0
Kharkof	8249	21.6	21.6	18.8	21.9	22.8	13.8	12.0	2.7	1.0	0	0	0	0	0	0
Oro	8220	20.8				23.4	13.1	9.8	3.6	1.8	0	0	0	0	0	0
Ridit	6703	23.2				27.3	17.8	5.7	1.4	0.9	0	0	0	0	0	0
White Odessa	4655	28.9	22.8	26.8	19.5	22.3	23.0	3.2	1.1	0.7	0	0	0	0	0	0
Fortyfold	4156	14.6				20.0	28.0	10.9	3.2	1.6	0	0	0	0	0	0
Triplet	5408	24.2				31.4	27.7	17.9	8.8	2.8	0	0	0	0	0	0
Regal	7364	25.5				22.8	18.1	14.6	8.8	4.0	0	0	0	0	0	0
Kanred	5146	18.1	21.6	19.4	25.3	26.5	25.7	23.4	18.9	1.0	1.5	0.7	0	0	0	0
Blackhull	6251	25.0	15.6	21.0	23.7	28.7	32.8	27.5	22.7	16.7	3.1	0.5	0	0	0	0
Turkey	7366	20.0	19.0	14.6	15.7	19.6	23.2	20.6	16.6	12.7	4.5	1.2	0	0	0	0
Pacific Bluestem	4067	19.3	17.6	23.9	23.1	30.9	29.2	31.8	22.9	18.3	15.9	9.9	7.7	5.6	0	0
Federation	4734	30.4	27.5	25.7	38.2	31.2	26.0	26.3	26.4	23.0	25.9	16.3	12.7	9.8	0	0
Hybrid 63		24.7	21.3	24.8	24.3	25.7	29.0	34.2	24.9	21.8	14.0	9.0	4.9	4.5	1.0	0
Marquis	4158		13.2	15.4	23.5	19.8	23.2	22.3	20.0	16.0	20.4	15.8	13.9	9.1	8.3	0
Hard Federation	4733		26.3	32.4	28.4	27.4	23.5	24.3	23.4	18.3	26.3	21.5	21.2	14.5	4.8	0
Weight per bushel (pounds):																
Hybrid 128	4512	57.6	54.3	55.0	54.0	55.0										
Kharkof	8249	58.2	55.1	52.0	54.3	57.0	56.0									
Oro	8220	58.0				56.8	56.6									
Ridit	6703	55.0				54.0										
White Odessa	4655	57.5	59.0	57.0	58.0	57.8	57.5									
Fortyfold	4156	56.6				54.0	51.8	49.1								
Triplet	5408	59.5				55.8	55.0	56.6								
Regal	7364	57.0				57.0	53.5	57.0								
Kanred	5146	56.5	54.0	50.6	53.6	55.6	54.8	56.7	56.3							
Blackhull	6251	55.5	52.5	52.6	54.0	56.0	54.5	56.0	56.0	57.5						
Turkey	7366	55.9	53.2	47.5	50.3	51.1	52.9	54.2	54.0	55.0						
Pacific Bluestem	4067	56.1	51.0	52.1	53.5	54.5	55.1	55.5	53.0	52.5	53.1					
Federation	4734	55.5	49.1	49.8	53.0	52.5	50.5	52.8	51.1	52.0	51.0	54.3	49.1			
Hybrid 63		57.5	56.6	57.0	56.8	58.0	58.8	58.7	57.2	58.1	57.0					
Marquis	4158		47.1	49.0	52.3	54.0	54.0	53.2	53.0	52.0	51.8	53.1	49.0			
Hard Federation	4733		54.0	53.5	55.8	58.0	50.5	52.1	50.0	50.0	53.1	53.1	53.5	47.5		

[a] The emergence dates may have varied 1 or 2 days from the averages given.
[b] Due to snow covering exact date of emergence not determined.
[c] None or only very few green heads, Sept. 10.
[d] Very poor stand due dry seed bed, but headed normally.

TABLE 5.—*Dates first and fully headed, plant height, yield, and bushel weight of eight varieties of wheat seeded in nursery rows at intervals during the season of 1926–27 at Moro, Oreg.*

Item and variety	C. I. No.	Date sown (first) and date emerged [a] (second)							
		Oct. 20 Nov. 1	Feb. 15 Mar. 12	Feb. 25 Mar. 16	Mar. 7 Mar. 22	Mar. 14 Mar. 31	Mar. 21 Apr. 8	Mar. 26 Apr. 14	Apr. 2 Apr. 17
Date first headed:									
Hybrid 128	4512	June 5	June 17	June 21	June 30	July 1	[b]	[b]	[b]
Kharkof	8249	June 4	...do...	June 17	June 20	June 22	June 28	July 5	July 10
Kanred	5146	...do...	June 16	June 18	June 21	June 24	July 1	July 6	July 11
Turkey	7366	...do...	June 15	...do...	June 19	June 21	June 27	...do...	July 7
Pacific Bluestem	4067	June 15	June 11	June 12	June 15	June 16	June 16	June 17	June 20
Federation	4734	June 12	June 6	June 8	June 9	June 10	June 11	June 13	June 16
Marquis	4158	June 13	June 11	June 12	June 14	June 15	June 15	June 16	June 18
Hard Federation	4733	June 5	May 31	June 2	June 4	June 5	June 6	June 8	June 9
Date fully headed:									
Hybrid 128	4512	June 11	June 25	July 16					
Kharkof	8249	June 10	June 24	June 24	July 6	July 11	July 17	July 24	Aug. 1
Kanred	5146	...do...	June 21	...do...	July 3	July 8	July 18	July 25	Aug. 2
Turkey	7366	June 11	June 19	June 21	June 24	July 5	July 8	July 21	July 27
Pacific Bluestem	4067	June 21	June 18	June 19	June 20	June 21	June 21	June 22	June 29
Federation	4734	June 18	June 12	June 16	June 18	June 18	June 18	June 19	June 22
Marquis	4158	...do...	June 18	June 19	June 19	June 19	June 19	June 20	June 23
Hard Federation	4733	June 13	June 8	June 10	June 12	June 13	June 14	June 15	June 16
Plant height (inches):									
Hybrid 128	4512	36	34	30	22	17			
Kharkof	8249	33	32	30	29	32	31	25	22
Kanred	5146	34	33	25	31	30	31	31	26
Turkey	7366	36	34	29	32	30	34	30	26
Pacific Bluestem	4067	34	39	33	38	39	37	36	37
Federation	4734	25	32	27	22	31	31	26	27
Marquis	4158	31	32	32	31	36	34	31	34
Hard Federation	4733	26	28	24	25	27	25	25	28
Bushels per acre:									
Hybrid 128	4512	33.2	32.7	29.1	10.5	9.1	0	0	0
Kharkof	8249	30.1	25.4	32.8	33.4	33.4	22.6	16.1	7.8
Kanred	5146	22.0	24.1	21.1	26.8	28.8	22.9	20.5	11.7
Turkey	7366	30.1	23.1	32.6	27.0	26.0	23.7	21.6	20.9
Pacific Bluestem	4067	27.0	29.2	27.8	32.7	35.7	29.7	23.8	29.9
Federation	4734	26.6	37.9	31.7	38.9	40.7	42.1	40.2	37.9
Marquis	4158	22.1	31.7	33.1	32.8	34.0	27.1	30.0	30.7
Hard Federation	4733	20.8	32.6	23.0	35.3	34.8	31.0	30.4	35.5
Weight per bushel (pounds):									
Hybrid 128	4512	60.5	54.0						
Kharkof	8249	63.0							
Kanred	5146	61.5	56.0	62.0		58.0	55.0	58.0	
Turkey	7366	62.0	55.0	56.5	57.0	55.0	52.0	56.0	56.5
Pacific Bluestem	4067	60.0	54.5	60.0	54.5	56.0	58.0	59.0	55.0
Federation	4734	60.0	56.0	60.0	59.0	60.5	59.0	60.0	59.0
Marquis	4158	60.5	58.0	60.5	57.0	59.0	58.0	58.0	58.0
Hard Federation	4733	61.0	61.0	61.5	61.0	61.0	61.0	58.0	61.0

[a] The emergence dates may have varied 1 or 2 days from the averages given.
[b] None or only very few green heads Sept. 10.

TABLE 5.—*Dates first and fully headed, plant height, yield, and bushel weight of eight varieties of wheat seeded in nursery rows at intervals during the season of 1926–27 at Moro, Oreg.*—Continued

Item and variety	Date sown (first) and date emerged [a] (second)								
	Apr. 9 Apr. 19	Apr. 16 Apr. 25	Apr. 23 May 2	Apr. 30 May 7	May 7 May 15	May 15 May 22	May 23 May 29	May 31 June 6	July 6 July 11
Date first headed:									
Hybrid 128	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	----------
Kharkof	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	----------
Kanred	July 19	[b]	[b]	[b]	[b]	[b]	[b]	[b]	----------
Turkey	July 11	July 19	[b]	[b]	[b]	[b]	[b]	[b]	----------
Pacific Bluestem	June 21	July 2	July 7	July 11	July 14	July 22	July 28	[b]	----------
Federation	June 19	June 23	June 30	July 5	July 10	July 19	July 25	Aug. 3	----------
Marquis	...do...	June 21	June 24	July 1	July 5	July 11	July 18	July 22	Aug. 27
Hard Federation	June 11	June 14	June 15	June 20	June 24	July 2	July 9	July 14	Aug. 18
Date fully headed:									
Hybrid 128	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kharkof	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kanred	----------	----------	----------	----------	----------	----------	----------	----------	----------
Turkey	July 29	Aug. 4	----------	----------	----------	----------	----------	----------	----------
Pacific Bluestem	July 3	July 10	July 12	July 17	July 22	Aug. 2	----------	----------	----------
Federation	June 28	July 3	July 8	July 13	July 28	Aug. 3	----------	----------	----------
Marquis	June 27	June 30	July 3	July 10	July 11	July 17	July 22	July 26	Sept. 15
Hard Federation	June 18	June 18	June 21	June 28	July 3	July 11	July 19	July 24	Sept. 7
Plant height (inches):									
Hybrid 128	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kharkof	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kanred	18	----------	----------	----------	----------	----------	----------	----------	----------
Turkey	23	22	----------	----------	----------	----------	----------	----------	----------
Pacific Bluestem	39	36	36	29	27	22	17	----------	----------
Federation	29	29	34	28	27	22	17	14	----------
Marquis	34	33	35	34	30	26	23	20	----------
Hard Federation	31	26	28	28	26	23	23	20	----------
Bushels per acre:									
Hybrid 128	0	0	0	0	0	0	0	0	----------
Kharkof	0	0	0	0	0	0	0	0	----------
Kanred	8.3	0	0	0	0	0	0	0	----------
Turkey	16.5	5.9	0	0	0	0	0	0	----------
Pacific Bluestem	26.7	30.0	15.5	19.4	16.6	15.7	15.7	0	----------
Federation	35.8	39.1	24.9	18.9	16.5	12.5	13.4	11.4	----------
Marquis	27.6	27.5	17.9	13.8	16.8	17.9	22.1	12.2	----------
Hard Federation	33.1	34.8	27.5	22.7	25.6	18.1	16.3	11.8	----------
Weight per bushel (pounds):									
Hybrid 128	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kharkof	----------	----------	----------	----------	----------	----------	----------	----------	----------
Kanred	----------	----------	----------	----------	----------	----------	----------	----------	----------
Turkey	----------	----------	----------	----------	----------	----------	----------	----------	----------
Pacific Bluestem	53.5	57.0	48.5	----------	----------	----------	----------	----------	----------
Federation	54.0	58.0	49.0	----------	----------	----------	----------	----------	----------
Marquis	58.0	60.5	54.0	----------	----------	----------	----------	----------	----------
Hard Federation	59.0	60.0	59.0	----------	----------	----------	----------	----------	----------

[a] The emergence dates may have varied 1 or 2 days from the averages given.
[b] None or only very few green heads Sept. 10.

EFFECT OF SEASON ON DATE OF HEADING AND YIELD

In these experiments for all winter varieties there was a critical date for sowing, the varieties if sown after that date producing few or no heads during the same season. This is especially well illustrated by Hybrid 128, which did not head when sown after about February 15. There is, however, some variation in this critical date from season to season. Thus, Hybrid 128 did not head normally in 1926 when sown after February 8, while in 1927 it headed normally when sown as late as February 25. The critical date for sowing Hybrid 128 was 9 days later in 1925 and 20 days later in 1927 than in 1926. The differences were even greater for other varieties. This variation from season to season apparently is correlated with differences in temperature, amount of sunshine, and other factors, the combined effect of which is to produce an internal condition in the plant, caus-

ing it to head and set seed. The mean monthly temperature for the months February to June average 5.0 degrees above normal in 1926, 3.1 degrees in 1925, and 0.4 degrees in 1927. The average number of clear or partly clear days for the months February to June was 20 in 1926, 15 in 1925, and 18 in 1927.

The critical period for any variety covers a very short interval. Thus, Hybrid 128 when sown on February 16 in 1925 produced a yield of 24.8 bushels to the acre, but when sown on March 10, 22 days later, only a prostrate vegetative growth with no heads was produced.

Federation and Pacific Bluestem, which are commonly classed as spring varieties, did not head when sown very late in the spring. The critical sowing date for normal heading of Federation and Pacific Bluestem was reached before May 21 in 1926, but was later than May 31, the last sowing date, in 1927.

The failure to produce heads normally when the seed is sown after the critical date is naturally accompanied by a marked reduction in yield. As would be expected, this decrease is proportional to the

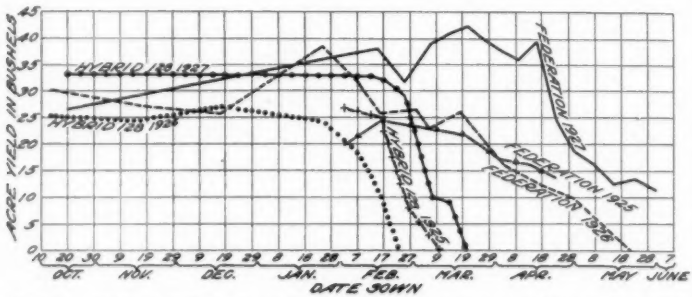

FIGURE 2.—Yields of Hybrid 128 and Federation wheats when sown at intervals during the seasons of 1925, 1926, and 1927 at Moro, Oreg.

degree of normal heading. The yields for Hybrid 128 and Federation during the three years are shown in Figure 2. The curves for Hybrid 128 emphasize the occurrence of the critical date about February 15 and its variation from season to season. The yields of Federation also were reduced by late seeding, but the effect was not so pronounced and sharply defined.

COMPARISON OF VARIETIES

The first-spring sowing dates from which a decided drop in yield was obtained and the first sowing dates from which no heads were produced are listed in Table 6 for each of 20 varieties. The varieties are listed in this table in the order of the earliness of their critical dates. They form a series ranging from Hybrid 128, which did not head when sown after about March 1, to Marquis and Hard Federation, which in these experiments produced heads from all dates of seeding.

The response of the different varieties is best brought out in the 1926 data, which cover a more complete series of sowing dates than for the other seasons. The dates of first heading of Hybrid 128, Kharkof, Kanred, Federation, Marquis, and Hard Federation when sown on the different dates during this season are shown graphically

in Figure 3. Yields for the same varieties are similarly shown in Figure 4.

The critical seeding dates for the winter varieties were in the same relative order each year.

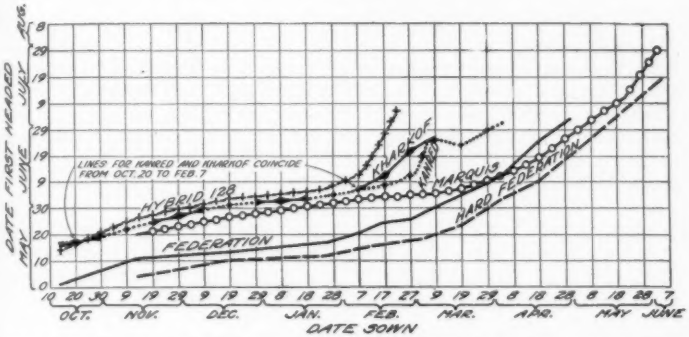

FIGURE 3.—Date of first heading of six varieties of wheat sown at intervals from October 14, 1925, to June 4, 1926, at Moro, Oreg.

TABLE 6.—*First dates of sowing from which a decided lowering in yield was obtained and the earliest sowing dates producing no heads for 20 wheat varieties grown at Moro, Oreg., during the crop years 1925, 1926, and 1927*

Variety	C. I. No.	First date of seeding giving a significant drop in yield			Earliest date of seeding producing no heads		
		1925	1926	1927	1925	1926	1927
Hybrid 128	4512	Feb. 26	Feb. 8	Mar. 7	Mar. 10	Mar. 1	Mar. 21
Kharkof	8249	Mar. 10	Feb. 15	Mar. 21	Apr. 13	Mar. 18	Apr. 9
Oro	8220	---do---	---do---	----------	----------	---do---	----------
Ridit	6703	----------	---do---	----------	----------	---do---	----------
White Odessa	4655	----------	Feb. 22	----------	----------	---do---	----------
Fortyfold	4156	----------	---do---	----------	----------	---do---	----------
Triplet	5408	----------	---do---	----------	----------	---do---	----------
Regal	7364	----------	---do---	----------	----------	---do---	----------
Kanred	5146	Mar. 20	Mar. 1	Mar. 21	Apr. 13	Apr. 16	Apr. 16
Blackhull	6251	----------	---do---	----------	----------	---do---	----------
Turkey	7366	Mar. 20	---do---	Apr. 9	Apr. 23	---do---	Apr. 23
Pacific Bluestem	4067	Apr. 2	---do---	Apr. 23	(a)	May 21	May 31
Federation	4734	---do---	Apr. 3	---do---	(a)	---do---	(b)
Hybrid 143	4513	Mar. 20	----------	----------	(a)	----------	----------
Hybrid 63	----------	Apr. 2	Mar. 1	----------	(a)	June 4	----------
Jenkin	----------	---do---	----------	----------	(a)	----------	----------
Marquis	4158	Mar. 20	Apr. 3	Apr. 23	(a)	(c)	(c)
Baart	1697	Apr. 2	----------	----------	(a)	----------	----------
Galgalos 39	----------	Apr. 13	----------	----------	(a)	----------	----------
Hard Federation	4733	----------	Apr. 30	May 15	(a)	(c)	(c)

[a] Headed from Apr. 23 date of seeding, which was the last one made in 1925.
[b] Headed from May 31 date of seeding, which was the last one made in 1927.
[c] Headed from June 4, 1926, and July 6, 1927, dates of seeding, which were the last made.

The critical dates determining marked yield reduction for the varieties followed the same order as for the critical dates governing heading. This is shown by comparing Figures 3 and 4.

It is of interest to note the difference in the growth habits of the varieties of the Turkey type when sown in late February, March, or early April. Kanred, for instance, headed and produced a fair yield of grain when sown as late as March 1. Kharkof, sown at the same time, was almost a failure. Blackhull and Turkey (C. I. 7366) were even less sensitive to late seeding than Kanred.

Federation and Pacific Bluestem heretofore have been considered true spring varieties. In these experiments they did not head when sown on May 21 and on June 4 in 1926, but produced only a flat vegetative growth. These varieties therefore should be considered as intermediate. They carry a factor for winter-growth habit, but their critical sowing dates are later than the normal date for seeding spring wheat in Oregon.

The true spring varieties, Marquis and Hard Federation, produce heads when sown at any time the summer, provided sufficient moisture is present for germination and growth and they are not killed by frost. Volunteer Hard Federation plants have been observed coming into head in November. Hard Federation and Marquis sown on June 4, 1926, were starting to head July 18 and July 31, respectively, 44 and 57 days after seeding. Sunset and Quality, sown July 6, 1927, were first headed August 10 and fully headed August 29 and September 9, respectively. The low yields of these varieties from late seedings are due partially to poor stands and unfavorable growth conditions caused by high temperatures and dry soil.

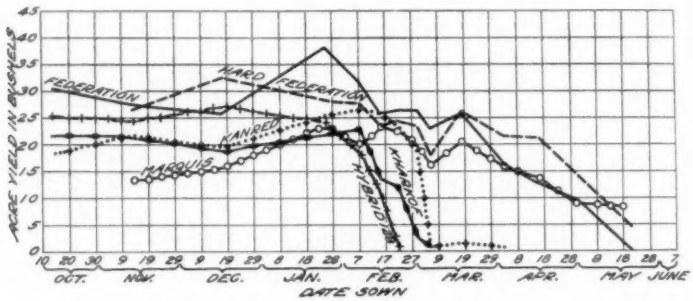

FIGURE 4.—Yield of six varieties of wheat sown at intervals from October 14, 1925, to May 21, 1926, at Moro, Oreg.

In general, wheat varieties head in the same relative order when sown on different dates during the season. Some varieties vary from this tendency. When sown November 13, 1925, Federation headed nine days earlier than Marquis; sown on April 3, 1926, they headed on the same day; and sown on April 30, Marquis headed six days earlier. Sown on May 21, Federation produced only a prostrate vegetative growth and did not head, whereas Marquis headed normally. The reversal is well shown in Figure 3. The same reversal also occurred in 1925 and 1927, although the dates when the change took place varied with the season. Marquis varied less in heading date when the sowing date was varied than did any of the varieties studied.

The plants were shorter from the later sowings of each variety. The data show no consistent relation between sowing date and weight per bushel, although in general later sowing gave lower test weights.

SUMMARY

The data presented show that the date on which wheat will head depends on variety, date of sowing, and seasonal environmental factors.

Every wheat variety which carries a factor for winter-growth habit, if sown after a critical spring date characteristic for that variety, will not head the same season but will produce a prostrate excessive vegetative growth. If not injured by drought or winterkilled, it will head the second season at about the normal date.

There is a wide variation in date of heading between varieties seeded on the same date.

Varieties headed in the same relative order for comparable seeding dates during different seasons, although the actual heading dates varied with the season.

Some varieties varied in relative order of heading for different seeding dates during the same season.

The critical sowing date for yield is earlier than the critical date for heading.

The critical planting date for normal heading at Moro, Oreg., was as early as February 15, for Hybrid 128. This critical date for Federation was not reached until April 30. The varieties studied showed a range from Hybrid 128, with the earliest critical date, to Marquis and Hard Federation, which apparently have none but will head when sown at any time if moisture and temperature are favorable for growth.

The critical dates are earlier in those seasons when the growing season is early and when temperatures are higher than in seasons when the reverse is true.

The growth phases of wheat, such as jointing and heading, are not completely controlled by any one specific environmental factor, such as temperature or the relative length of day, but are influenced by the entire environmental complex.

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THE VITAMIN A CONTENT OF OATS[1]

By CLARA R. MEYER, *Research Assistant in Nutrition*, and ROSSLEENE ARNOLD HETLER, *Associate Chief in Nutrition, Department of Home Economics, Agricultural Experiment Station of the University of Illinois*

INTRODUCTION

In 1917, McCollum [2] designated fat-soluble vitamin A, along with proteins and inorganic salts, as a dietary deficiency of the oat kernel. He says:

> The unidentified dietary factor fat-soluble A is present in very small amount in the oat kernel. It is not possible to supplement the oat kernel with inorganic salts and purified protein so as to induce growth beyond the third month. The inclusion of butter fat or some other substance which supplies the unknown A prevents the failure at this point * * *.

This finding of McCollum was confirmed in 1927 by Steenbock and Coward,[3] who irradiated the basal food to supply vitamin D. They found that when oats, as the sole source of vitamin A, made up 68 per cent of the basal synthetic ration, ophthalmia developed in rats in 5½ to 6½ weeks, and 3 of the 4 animals died shortly after that time.

Since Sure [4] had found that vitamin A could be detected in wheat oil when the wheat itself appeared to be lacking in this factor, and Meyer and Hetler [5] had demonstrated a slight concentration of vitamin A in the crude oil pressed from corn germs, it was thought possible that some vitamin A might be detected in the fat of the oat kernel. Accordingly, oat oil as well as the oat kernel was tested for this vitamin.

EXPERIMENTAL PROCEDURE

The curative method for the quantitative determination of vitamin A as described in detail by Meyer and Hetler was used throughout this study. Rats were employed as the experimental animals. The experimental period was started when the rats were 28 to 30 days of age and weighed approximately 50 grams. A vitamin-A-free irradiated basal diet, supplemented with dried brewer's yeast (five-tenths gram daily) to furnish vitamins B and G, was given the test animals, and they were allowed access to the diet at all times. The basal diet was prepared as formerly described,[6] and was composed of the following ingredients:

	Per cent		Per cent
Extracted casein	18	Starch	57
Osborne-Mendel salt mixture	4	Sodium chloride	1
Crisco	20		

[1] Received for publication Nov. 3, 1930; issued April, 1931.

[2] MCCOLLUM, E. V., SIMMONDS, N., and PITZ, W. THE NATURE OF THE DIETARY DEFICIENCIES OF THE OAT KERNEL. Jour. Biol. Chem. 29: 341-354, illus. 1917.

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[6] MEYER, C. R., and HETLER, R. A. Op. cit.

With the depleted animals used (from mother rats receiving a diet low in vitamin A) definite eye symptoms usually preceded cessation of growth and developed from 25 to 35 days after the experimental period began. As soon as definite ophthalmia developed, ground whole hull-less oats as the sole source of vitamin A replaced the same percentage of starch or Crisco, or parts of both the starch and the Crisco, in the diet. Later work included the use of oat oil incorporated in the diet or fed separately, as the sole source of vitamin A. The test period was eight weeks, except in the cases where death occurred before the end of that time.

A variety of naked oats, Illinois Hull-less, was used exclusively in this investigation. The oat oil was prepared by a method essentially the same as that used by Sure[7] in the preparation of acetone-extracted wheat-germ oil. The ground whole oats were dried in shallow pans at a depth of about one-half inch in vacuo at 50° C. for 10 hours. About 500 grams of the dried oats were placed in flasks, covered with cold acetone, thoroughly shaken for several minutes, and allowed to stand 10 to 12 hours. The solvent was then filtered off and the oats were further extracted by percolating with cold acetone until no color was visible in the solvent. The combined extracts were dried in the air at room temperature to remove all but the last portion of the acetone, which was completely removed by drying in vacuo at 35° for 3½ hours. It was found that by this method about 3.75 per cent by weight of oil could be extracted from the oats. Munro and Rae[8] state that fresh oats contain about 4.8 per cent oil. The oil was greenish brown in color and readily hardened when placed in the refrigerator, where it was always stored.

When oat oil was incorporated in the food only one or two days' supply of the ration was made up at a time, and the usual procedure of irradiating the basal food before the addition of the test material was followed. Fresh food was given to the animals daily. When the oat oil was fed separately it was found that by placing the yeast on top of the oil, the latter was readily consumed along with the yeast.

A negative control animal was maintained in each litter on the vitamin-A-free basal diet alone. Cod-liver oil, 8 drops daily, was fed to other control animals which had developed severe ophthalmia. In order to make sure that the oat oil was not toxic and that the arrested growth and decline of the animals receiving the oat oil were due solely to vitamin A deficiency, cod-liver oil was given along with the oat oil to one or two animals in each group, in every case after the animal had reached a critical condition.

The potency of the vitamin A in the experimental material was determined by comparing the test animals and the controls in respect to eye condition and growth.

EXPERIMENTAL RESULTS

The data submitted in Table 1 and Figure 1 show clearly that whole hull-less oats are almost if not totally lacking in vitamin A. Although the experimental animals continued to grow for some time after the

[7] SURE, B. DIETARY REQUIREMENTS FOR REPRODUCTION. V. THE RÔLE OF VARIOUS VEGETABLES AND FRUIT OILS IN FERTILITY AND LACTATION. Jour. Biol. Chem. 69: 29–40. 1926.

[8] MUNRO, L. A., and RAE, W. J. DETERMINATION OF THE ANTIRACHITIC PROPERTIES OF OAT OIL. Sci. Agr. 10: 305–312, illus. 1930.

development of ophthalmia and following the inclusion of oats in the diet, the ophthalmic condition was never alleviated, and became increasingly more severe. In every case where diets including the 10, 30, or 60 per cent levels of oats were fed, growth finally ceased and a rapid decline in weight followed. Death occurred before the end of the 8-week test period. All negative control rats, or animals receiving the basal diet alone, died about 30 days after the development of ophthalmia. When 8 drops daily of cod-liver oil were given

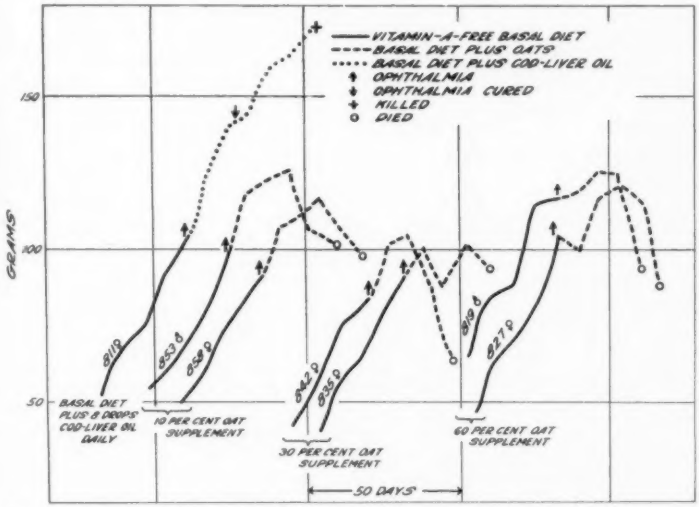

FIGURE 1.—Weight curves of rats receiving vitamin-A-free diets supplemented with different percentages of whole hull-less oats. Ophthalmia was never cured and death resulted in every case. The weight curve of an animal with ophthalmia cured by cod-liver oil is included

to animals in which ophthalmia had developed while they were on a vitamin-A-free basal diet, the eyes were completely cured within a few days. If the eye condition was allowed to become very severe, however, a period as long as two weeks was necessary in order to effect a permanent cure with cod-liver oil. Tabulated data of control animals are not included here, but the results were very similar to those presented in the data for control animals by Meyer and Hetler[9] in 1929.

TABLE 1.—*The effect of whole hull-less oats on ophthalmia and growth of vitamin A deficient rats*

Rats used	Quantity of oats fed		Effect on ophthalmia	Effect on growth
	Per cent of the diet	Average weight fed daily [1]		
Number		*Grams*		
5	10	0.6–0.8	Not cured	Decline and death in 30–33 days.
6	30	1.6–2.4	do	Decline and death in 25–33 days.
6	60	2.4–5	do	Decline and death in 17–35 days.

[1] Calculated from total daily food consumption.

[9] MEYER, C. R., and HETLER, R. A. Op. cit.

When the acetone-extracted oat oil was included as a possible source of vitamin A in the diet of ophthalmic rats, the condition of the animals

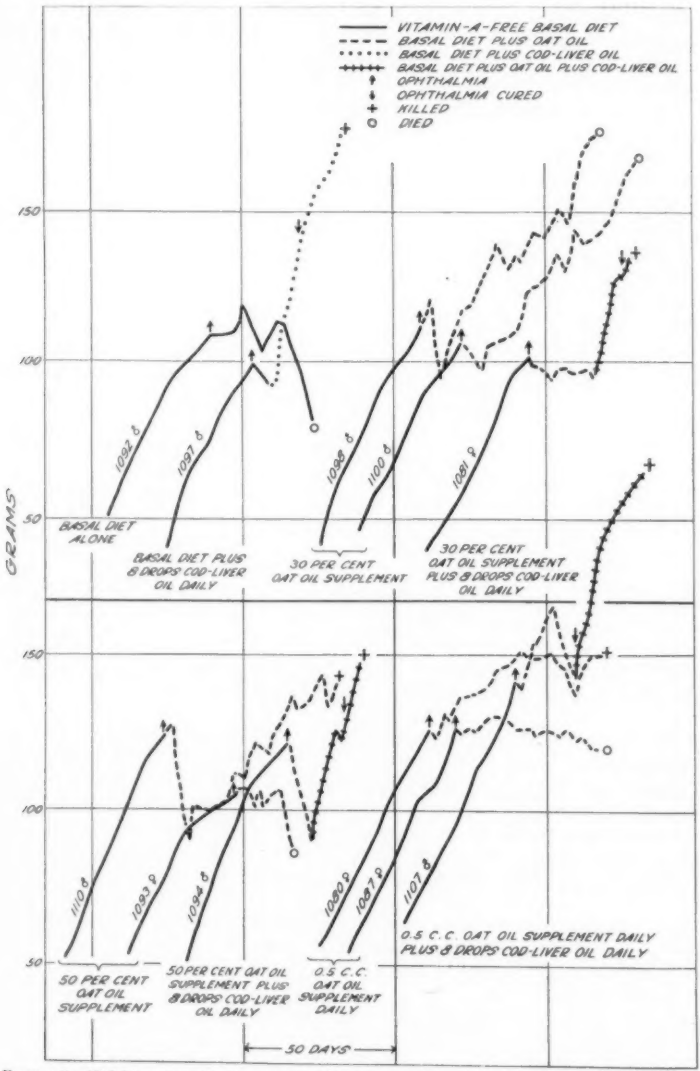

FIGURE 2.—Weight curves of rats receiving vitamin-A-free diets supplemented with oat oil alone, and with both oat oil and cod-liver oil. When the vitamin-A-free basal diet was supplemented by oat oil alone ophthalmia was never cured, growth was arrested, and several animals died. When cod-liver oil was fed with the oat oil, ophthalmia was cured and an excellent nutritive condition was attained. Weight curves of control animals not receiving oat oil are included

was slightly better than that of rats receiving whole hull-less oats as the sole source of vitamin A. Table 2 and Figure 2 show the results

obtained when the oat oil was fed at different levels in the diet. Since the acetone extraction gave about 3.75 per cent oil by weight from the oats, 1 gram of oat oil represents the acetone-soluble portion of about 27 grams of oats. The oat oil was not only incorporated in the diet at 50 and 30 per cent levels but was also fed separately as 0.5 cubic centimeter daily. The animals receiving 50 per cent oat oil in the diet consumed less food, and thus actually obtained approximately the same amount of oat oil daily as the animals receiving only 30 per cent oat oil in the diet. When cod-liver oil was given to animals in each of these groups, however, the food intake of the rats increased, and in the cases where cod-liver oil was fed along with the 50 per cent oat oil an average of 4 grams daily of the oat oil was consumed. The complete cure of ophthalmia in 7 to 14 days and the excellent nutritive condition of these rats indicate that the poor condition of all of the animals receiving oat oil as the sole source of vitamin A was not due to a toxic effect of the oat oil, but to a deficiency of vitamin A.

TABLE 2.—*The effect of oat oil on ophthalmia and growth of vitamin A deficient rats*

Rats used	Quantity of oat oil fed		Effect on ophthalmia	Effect on growth
	Per cent of the diet	Average weight fed daily		
Number	50	*Grams*		
8		[1] 1.6	Not cured, several animals showed slight improvement.	Slow or arrested growth; 1 animal died.
2	50	[1 2] 4	Cured with cod-liver oil	Decline; death imminent; cured with cod-liver oil.
10	30	[1] 1.6	Not cured, several animals somewhat improved.	Grew slowly, no deaths.
1	30	[1 2] 1.8	Cured with cod-liver oil	Cessation of growth; almost dead; completely cured with cod-liver oil.
10	[1] 5	[3] .38	Not cured, severe ophthalmia	Arrested growth; decline; 1 animal died.
1	[1 2] 3.7	[3] .38	Cured with cod-liver oil	Almost dead; completely cured with cod-liver oil.

[1] Calculated from total daily food consumption.
[2] With 8 drops of cod-liver oil, given daily.
[3] Fed separately as 1 cubic centimeter (or 0.38 gram) daily.

The slow growth and prolongation of life (except in one case, Table 2) over an 8-week period, together with the slight improvement although never permanent cure of ophthalmia in rats fed the larger amounts of oat oil, probably indicate the presence of a very small amount of vitamin A in the oat oil. The quantity present was little more than a trace, however, since it could be detected only when the oat oil was fed at 30 or 50 per cent levels, or approximately 1.6 grams daily. 1.6 grams represents the fat-soluble portion of approximately 43 grams of whole oats, or an amount of oats far too large for a rat to consume daily.

A very recent report by Munro and Rae [10] describes tests for vitamin D in oat oil. These investigators used chickens as the experimental animals, and studied the antirachitic properties of irradiated and nonirradiated oat oil which had been prepared on a large scale

[10] MUNRO, L. A., and RAE, W. J. Op. cit.

in their laboratory. The solvent used was a low-boiling fraction from high-test gasoline. The results showed that the oat oil was of no value as an antirachitic agent either before or after irradiation. It appears, therefore, that oat oil is of little if any value as a source of either vitamin D or vitamin A.

SUMMARY

An investigation was made of the vitamin A content of whole hull-less oats and of the acetone-extracted oil of whole hull-less oats. Rats were used as the experimental animals. Ophthalmia was not cured and death occurred when whole oats at levels of 10, 30, or 60 per cent of the diet, or from 0.6 to 5 grams daily, were fed to vitamin A depleted animals. When oat oil was fed at levels as high as 30 and 50 per cent of the diet, or 1.6 grams daily, to vitamin A deficient rats, ophthalmia was never entirely cured, but a slight improvement of the eye condition was noted in several cases. All but one animal lived throughout the 8-week test period, but growth was very slow or was completely arrested. It was concluded that a very small amount of vitamin A is present in oat oil.

The rapid cure of ophthalmia and the resumption of growth which occurred when cod-liver oil was added to the diet of rats that were declining on a diet in which oat oil furnished the sole source of vitamin A, show that the poor condition of these animals was not due to a toxic effect of the supplement but to a deficiency of vitamin A in the oat oil.

INHERITANCE IN A WHEAT CROSS BETWEEN HYBRID 128 × WHITE ODESSA AND KANRED[1]

By GEORGE STEWART, *Agronomist*, and R. W. WOODWARD, *Graduate Student, Department of Agronomy, Utah Agricultural Experiment Station*

INTRODUCTION

The genetic data herein presented were obtained from a wheat cross which was made primarily to develop a variety of wheat resistant to bunt, *Tilletia tritici* (Bjerk.) Wint. The parents used were a homozygous bunt-resistant strain obtained from the Washington experiment station, Hybrid 128 × White Odessa, and a pure line of Kanred.

LITERATURE

Biffen (*1*)[2] was the first to work on the inheritance of awns in wheat.

The Howards (*7*) crossed a fully awned wheat with a fully awnless one and found 15 awned : 1 awnless when all degrees of awned plants were grouped together.

Clark and Hooker (*4*) found in studying the inheritance of awns in Marquis × Hard Federation that a 1 : 12 : 3 ratio was obtained in one case and a 1 : 11 : 4 ratio in another. Hard Federation they classed as awnless and Marquis as awnletted. In the F_2 generation a close approximation to a 3 awnless : 1 awnletted ratio was obtained. If the awnletted and the intermediates were combined, a ratio of 15 awnletted : 1 awnless was obtained. A 2-factor difference is suggested to explain these results. Both parental types were recovered in the F_3 and one true-breeding intermediate class was produced.

Stewart and Heywood (*13*) in a study of a cross between Federation and F22, a hybrid of Sevier × Dicklow, which were awnless and awned, respectively, report four true-breeding awn classes and five segregating classes in the F_3 progenies. A ratio of 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1 was suggested and a rather close fit obtained. In this case the awn inheritance was explained on the basis of a 2-factor difference with independent segregation.

When Marquis and Federation wheats were crossed, Stewart and Tingey (*14*) found a 1-factor difference to explain the breeding behavior. In this case both parents were almost entirely awnless except for short apical beaks, and the F_3 progeny were either like the parents or bred true for apical awns or segregated for all three classes in a 1 : 2 : 1 ratio.

Gaines and Singleton (*5*) found in a Turkey × Marquis cross that when the fully awned F_3 progenies were compared with the remainder of the progenies, a 3 : 1 ratio was obtained for awnless and awned, respectively. If the heterozygous were considered a separate class from the pure dominant a 1 : 2 : 1 ratio resulted.

[1] Received for publication Nov. 3, 1930; issued April, 1931. Contribution from the department of agronomy, Utah Agricultural Experiment Station.

[2] Reference is made by number (italic) to Literature Cited, p. 520.

Clark, Florell, and Hooker (*3*) report crosses between Bobs, Hard Federation, and Propo in which five true-breeding awn classes were obtained. In this case the awnless condition was considered dominant, although there is no known record of real dominance for awn characters. Their results led them to suggest two major factors *AABB* for Bobs × Propo, two minor factors for Bobs × Hard Federation, and two major factors and one minor factor for Hard Federation × Propo which involved the five true-breeding awn classes. They concluded that from one to as many as four genetic factors may be involved in the inheritance of awnedness in wheat.

Parker (*9*), in a cross between a club and an ordinary wheat of intermediate density, obtained forms as compact as the more compact parent and a series of less dense forms, some of which were more lax than the more lax parent.

Stewart (*12*) found in a cross of Kanred × Sevier that the F_1 plants were intermediate for spike density but resembled the Sevier parent more closely than the Kanred. In the F_2, lines were found more dense than Sevier and more lax than Kanred. No true-breeding lines like the Sevier parent were recovered. The intermediates were all heterozygous, and a close fit to a 1 : 2 : 1 ratio was found, which agrees with Spillman's (*10*) data.

Stewart and Heywood (*13*) obtained the same results in a cross of Federation × a hybrid of Sevier × Dicklow. In both cases, the classification of spike types was based on measurements of a representative spike of each plant. The mean coefficients of variability for the spike density of parental rows were 9.81 per cent and 10.59 per cent, while for the F_3 lax progenies the mean coefficient of variability was 9.56 per cent and for the homozygous-dense progenies 10.70 per cent. The heterozygous rows showed a mean of 40.91 per cent, which makes the divisions rather clear-cut. A close approximation to the expected 1 : 2 : 1 ratio was obtained, indicating a single-factor difference in the parents.

Nilsson-Ehle, cited by Stewart (*11*), reports the presence of two lengthening factors in some crosses in order to explain the behavior of spike density.

The dominance of red kernel over white was first reported by Biffen (*1*). He found that in the F_1 generation all kernels were red, and in the F_2 there were 3 red : 1 white. Nilsson-Ehle first reported crosses in which ratios of 15 red : 1 white and 63 red : 1 white were obtained in the F_2 segregates. Clark (*2*) also found that red color is dominant, and that either one, two, or three factor differences may occur between crosses of various wheat varieties for this character. In the F_2 he obtained 95.1 per cent red and 4.9 per cent white, which if corrected on a 2-factor-difference basis, would be 93.75 per cent and 6.25 per cent, respectively. When he used Kota in a reciprocal cross as the female, a closer fit was obtained. In all tests the white bred true, while the red-kerneled plants threw segregates ranging from 63 red : 1 white, 15 red : 1 white, and 3 red : 1 white, depending on the cross.

Stewart (*12*) found a 3-factor difference in a Kanred × Sevier cross. As only from 30 to 40 plants were harvested from a row, the segregating group of 63 red : 1 white fell short of the calculated expectancy. By growing an F_4 series he was able to adjust this error to a great extent, and to settle doubtful cases in other groups as well.

Stewart and Tingey (*14*) studied the kernel color in a Marquis×Federation cross which indicated an apparent 2-factor difference. The closeness of fit in this case was shown by $P=0.6155$, which is considered very close.

Love (*8*) and Hayes (*6*) report a one, two, or three factor difference in various wheat crosses involving different varieties.

DESCRIPTION OF PARENTS

Kanred originated as a pure line from a Crimean wheat at the Kansas experiment station. It is very much like ordinary Turkey, but can be distinguished from it by the longer beaks on its glumes. It has a white glume with faint markings of bronze and a dark-red kernel. Its fusiform spike is a lax to mid-dense, and is fully awned. Kanred has the winter growth habit and is known to be susceptible to several physiologic forms of bunt. At the present time it is the most important wheat in the central Great Plains area, where it outyields ordinary Turkey and is believed to be a little more drought resistant. In parts of the intermountain region also, Kanred has been reported to outyield Turkey and is now becoming more popular than Turkey as a winter wheat.

Hybrid 128×White Odessa was obtained from Gaines of the Washington station. It is a homozygous strain for the characters studied and has white chaff and white kernels. The head type would be classed as club or dense and the upper third of the spike bears tip awns which in this study are classed as awns 2.

The various awn types of wheat have been arbitrarily grouped into four classes: Awns 1, awns 2, awns 3, and awns 4. Class 1 is free from awns except for short beaks and for one or more very short awn tips of the apex of the spike. Class 2 is characterized by awns ranging in length from 4 to over 20 mm. Awns in this class are generally distributed over the upper third of the spike. Class 3 awns are usually distributed over the upper two-thirds of the spike, being longer near the apex. Several short curly awns may be found below the longer ones, causing a wider range of variability to occur in this class than in any other class studied. Awn class 4 is the common fully awned type of which Turkey is a representative variety.

In Table 1 the contrasted characters of the parents studied in this cross are presented.

TABLE 1.—*Parental differences between Hybrid 128×White Odessa and Kanred wheats*

Variety	Awns	Spike density	Kernel color	Resistance to bunt smut
Hybrid 128×White Odessa	Apically awned	Club or dense	White	Highly resistant.
Kanred	Fully awned	Lax to mid lax	Dark red	Susceptible.

EXPERIMENTAL PROCEDURE

During the summer of 1926, the cross between a pure line of Hybrid 128×White Odessa and a pure line of Kanred was made at Newton, Utah, a few miles from the experiment station. The F_1 generation was grown in 1927 and the F_2 in 1928. One of the most vigorous

families was then chosen to continue the experiment. Segregates in the F_2 were so grouped that the F_3 progenies could be seeded systematically, according to the awn class, starting with awn class 2 followed in order by awn classes 3 and 4.

The F_3 progeny rows were spaced 12 inches apart and the kernels from each F_2 plant were used to seed one row. The kernels were spaced by hand without measuring from 2½ to 4 inches apart in the rows, making from 40 to 60 plants in a progeny row 12 feet in length. As the primary aim in making the cross was to get a good variety of wheat resistant to bunt, the F_2 kernels were dusted with all the smut spores that would remain on them.

Each F_3 progeny was used to represent the breeding behavior of the F_2 plant. This method has been found much more accurate, as genotypic differences may not clearly manifest themselves in the F_2 but show in the F_3. Often this method can be improved by again growing F_4 progenies when in doubt of F_3 results.

Too few parental rows were grown along with this cross for accurate comparisons of measured characters, but the data are included.

When the grain was mature, the F_3 rows were pulled separately and labeled, after which they were taken to the laboratory where each plant was carefully classified and measured. The data were taken shortly after harvest in order to permit the fall seeding of the most promising lines.

Owing to the artificial inoculation with smut of the F_2 seed, several F_3 rows contained fewer than 40 plants which had one or more normal spikes (i. e., free from bunt). Occasionally more than one-half of the individuals of a progeny would be completely smutty. When all the spikes of a plant contained bunt, kernel color and spike density could not be determined.

After the data were all taken, tabulated, and analyzed, the inheritance of each character was studied separately and a theory sought to explain the results. The inheritance of awns and kernel color in this cross were clear-cut cases of segregation which could be determined by observation, but with spike density a measurement of 10 internodes was thought to be more accurate. The mean value, the standard deviation, and the coefficient of variability were calculated for the spike density of each F_3 progeny.

INHERITANCE OF INDIVIDUAL CHARACTERS

Inheritance studies were made of the following individual characters: Awn classes, spike density, and kernel color.

AWN CLASSES

Although the F_1 plants resembled the Hybrid 128 × White Odessa parent for awn development more closely than they did the Kanred parent, they were intermediate. In the F_2, both parental types were recovered as well as a group of intermediates which segregated in the F_3. When the F_3 progenies were studied as a basis for the genotypic classification of the F_2 plants, 60 of the F_2 plants were shown to be homozygous for awns 2; 120 of the F_2 plants were heterozygous, throwing all three groups in the F_3 generation; and 54 plants were homozygous for awns 4. Figure 1 shows typical heads from F_3 plants for each of the classes found in this cross.

The length of the awns was not measured, as rather clear-cut segregation groups could be made by observation. Awns of class 2 seldom reached over 1 cm. in length and were limited to a few on the upper third of the spike. Awns of class 3 were not only considerably longer, but were generally more numerous and extended farther down the spike than did awns of class 2. The behavior of awns of class 3 in this cross was very different from that reported by the Howards (*7*) of India, who found that such awns are rather short but cover the larger portion of the spike. Awns of class 3, however, showed a greater range of variability than either of the true-breeding groups. The homozygous awns of class 4 showed some variation in length;

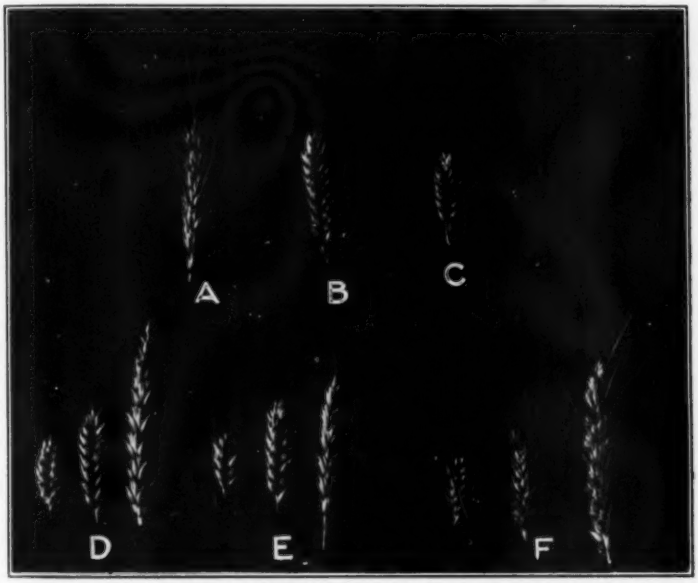

FIGURE 1.—Type of awns found in the three awn classes of Hybrid 128 × White Odessa and Kanred wheat, that appeared in the F_2 generation, the two parent types and the F_1 type: A, Kanred parent; B, F_1 type; C, Hybrid 128 × White Odessa parent; D, awn class 2; E, awn class 3; F, awn class 4

the lax spikes had longer awns than the dense ones, but in general they were very nearly like Kanred in this character, a behavior previously studied at some length (*12*).

The four awn classes found in the earlier study (*12*) were designated as follows:

Awn 4	*AABB*
Awn 3	*AAbb*
Awn 2	*aaBB*
Awn 1	*aabb*

Table 2 shows the three awn classes based on their genotypic differences, their expected ratio, and their breeding behavior on the assumption that a 1-factor difference is present, as the data of this cross seem to indicate.

TABLE 2.—*Three awn-class genotypes, their expected ratios, and their breeding behavior based on a 1-factor difference*

Awn-class No.	Expected ratio	Genotype	Expected breeding behavior
4	1	*AABB*	Breed true for awn class 4.
3	2	*AaBB*	Segregates for awns 2, 3, and 4.
2	1	*aaBB*	Breed true for awn class 2.

Table 3 shows the goodness of fit between the observed and calculated frequencies. On the basis of three awn classes, $\chi^2=0.4614$ and $P=0.8190$, which is a very good fit. A worse fit would be expected in 82 out of each 100 cases due to chance alone.

TABLE 3.—*Goodness of fit of three awn-genotype classes of F_2 progenies when compared with a 1:2:1 ratio which would be expected theoretically when a 1-factor difference segregates independently*

Item	Calculated value (C)	Observed value (O)	O−C	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Homozygous, awns of class 2	58.5	60	1.5	2.25	0.0385
Heterozygous	117	120	3	9	.0769
Homozygous, awns of class 4	58.5	54	−4.5	20.25	.3461

$\chi^2=0.4615$. $P=0.8190$.

SPIKE DENSITY

The F_2 breeding behavior for spike density was studied by a measurement of 10 rachis internodes on a leading spike of each F_3 plant. The extreme upper and the extreme lower internodes were avoided as they are more variable than the central ones. The first 40 of the plants were taken at random from each bundle and used to represent that particular F_2 plant which was their parent the previous year.

The homozygous progenies were separated from the heterozygous by a statistical method in which the coefficient of variability was used as the final basis. The parental rows of Kanred showed coefficients of variability ranging from 6 to 16 per cent, with a mean of 9.46 per cent. (Table 4.)

The range in coefficient of variability was not obtained for the Hybrid 128 × White Odessa parent, as only a single row was grown. This row, however, gave a coefficient of variability of 4.76 per cent. The homozygous-dense progenies showed a range in coefficients of variability of 1.26 to 9.85 per cent, with a mean of 6.29 per cent. The homozygous-lax progenies showed a range of from 3.26 to 11.48 per cent. There was one progeny the coefficient of variability of which was 23.14 per cent. The spike density of this row ranged from 46 to 60 mm. (the ordinary range for true-breeding lax progenies), and contained only 15 plants which were not completely affected with smut. On account of there being no really dense spikes the progeny was regarded as homozygous-lax. However, with as high a percentage of variability as was shown in this exceptional row, it might statistically be thought to overlap on the lowest coefficient of variability of the segregating rows, which is 25.96 per cent. This progeny might have been regarded as segregating, without affecting the conclusions in any way.

TABLE 4.—*Mean spike-density and coefficient-of-variability (C. V.) classes of Hybrid 128×White Odessa and Kanred wheat, and of the three groups of hybrid F_3 progenies, homozygous-dense, heterozygous, and homozygous-lax*

Parent or progeny	Number of plants in spike density classes (millimeters per 10 internodes) specified															
	18	21	24	27	30	33	36	39	42	45	48	51	54	57	Total	C. V. classes
																Per cent
Kanred	---	---	---	---	---	---	---	---	---	---	---	2	---	---	2	6.00
	---	---	---	---	---	---	---	---	---	---	---	5	1	---	6	9.00
	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12.00
	---	---	---	---	---	---	---	---	---	---	---	2	---	---	2	15.00
Total or mean	---	---	---	---	---	---	---	---	---	---	---	9	1	---	10	9.46
Hybrid 128×White Odessa	---	1	---	---	---	---	---	---	---	---	---	---	---	---	1	4.76
	1	2	---	---	---	---	---	---	---	---	---	---	---	---	3	2.60
Homozygous-dense	9	13	1	---	---	---	---	---	---	---	---	---	---	---	23	4.00
	9	22	---	---	---	---	---	---	---	---	---	---	---	---	31	6.00
	1	6	1	---	---	---	---	---	---	---	---	---	---	---	8	8.00
Total or mean	20	43	2	---	---	---	---	---	---	---	---	---	---	---	65	6.29
	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1	24.00
	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1	26.00
	---	---	---	1	2	1	---	---	---	---	---	---	---	---	4	28.00
	---	---	---	3	2	4	2	---	---	---	---	---	---	---	11	30.00
Heterozygous	---	---	---	---	6	11	1	---	---	---	---	---	---	---	18	32.00
	---	---	---	2	10	11	2	---	---	---	---	---	---	---	25	34.00
	---	---	1	6	16	7	1	---	---	---	---	---	---	---	31	36.00
	---	---	---	2	6	4	1	---	---	---	---	---	---	---	13	38.00
	---	---	---	4	2	---	---	---	---	---	---	---	---	---	6	40.00
	---	---	---	---	1	---	---	---	---	---	---	---	---	---	1	42.00
Total or mean	---	---	1	18	45	40	7	---	---	---	---	---	---	---	111	31.95
	---	---	---	---	---	---	---	---	---	1	11	10	---	---	22	2.00
	---	---	---	---	---	---	---	---	---	3	6	16	4	---	29	5.00
	---	---	---	---	---	---	---	---	---	---	1	2	2	---	5	8.00
Homozygous-lax	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	11.00
	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	14.00
	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	17.00
	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1	23.00
Total or mean	---	---	---	---	---	---	---	---	---	4	18	29	7	---	58	5.89

The heterozygous progenies had a coefficient of variability ranging from 26 to 42 per cent with a mean of 31.95 per cent. Only a few of the progenies showed less variability than 30 or greater than 35 per cent.

The coefficient-of-variability method of spike-density classification showed clear-cut separation of the three groups found in this cross with one exception mentioned previously, which falls close to the lower limits of the heterozygous expectancy.

The mean values for the coefficient of variability of both homozygous progeny groups were lower than the mean for Kanred and higher than the mean for Hybrid 128×White Odessa. Less variability, as shown by lower coefficients of variability, was obtained in the homozygous-dense group than in the homozygous-lax group. With one exception the coefficient of variability of the least variable heterozygous progeny exceeded the most variable of the homozygous groups by over 100 per cent.

Spikes and rachises from parents and progeny of the cross are shown in Figure 2, and spike-density curves are shown in Figure 3.

When the breeding behavior of the F_3 progenies was analyzed, there were found to be 65 homozygous for dense spikes, 111 heterozygous, and 58 homozygous for lax spikes. Since a complete F_3 progeny repre-

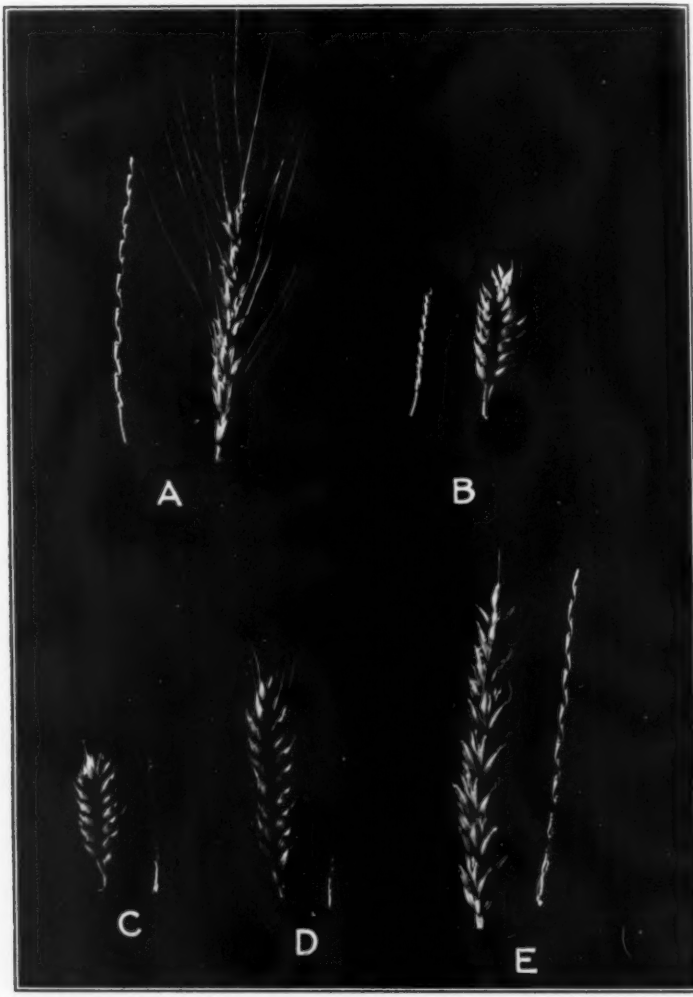

FIGURE 2.—Spikes and rachises from parents and progeny of the Kanred cross with Hybrid 128× White Odessa: A, Kanred parent; B, Hybrid 128×White Odessa parent; C, representative spikes and rachisof homozygous-dense progeny; D, typical spike and rachis of intermediate progeny group; E, spike and rachis of typical homozygous-lax F_3 progenies. Rather wide variation occurred in each F_3 spike-density group

sents an F_2 plant, the F_3 progeny gives a more accurate description of the F_2 plant than could be obtained by trying to determine the possible genetic composition of the plant itself. Both parental types were

recovered in the homozygous progenies. A simple 1:2:1 ratio was suggested as the logical theory to explain the data. The goodness of fit indicates that the theory was probably correct, since $P=0.5995$. The 1-factor difference is the more common result with spike density, but a few cases have been reported where a more complicated type of inheritance was observed (*7*, *9*, *11*, *12*, *13*).

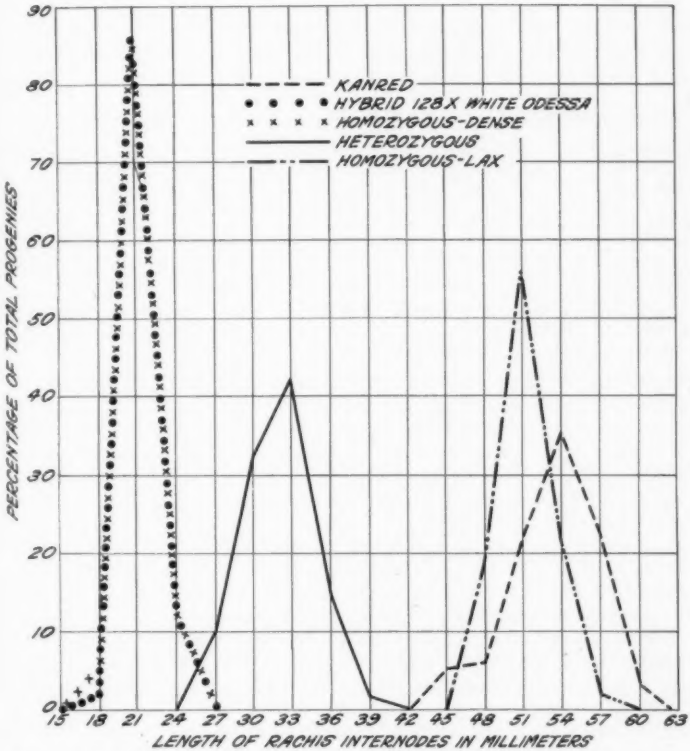

FIGURE 3.—Spike-density curves of Kanred and Hybrid 128 × White Odessa parents, and of the three progeny groups—homozygous-dense, heterozygous, and homozygous-lax

In Table 5 the goodness of fit is presented as compared to a 1:2:1 ratio.

TABLE 5.—*Goodness of fit of three groups of F_3 progenies for spike density compared with a 1:2:1 ratio*

Progeny group	Calculated value (C)	Observed value (O)	O−C	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Homozygous-dense	58.5	65	6.5	42.25	0.7222
Heterozygous	117	111	−6	36.00	.3077
Homozygous-lax	58.5	58	−0.5	.25	.0043

$\chi^2=1.0342$. $P=0.5995$.

Effect of Bunt on Spike Density

Smutty plants were avoided in taking the data for spike density, as it was obvious that they were not normal in this respect. Data are presented to show the actual lengthening effect of bunt on spike density, the writers not having observed any previous report to this effect.

Casual observation of an infected homozygous-dense progeny might lead one to pronounce it segregating in spike density, when in reality the presence of bunt might have caused a considerable lengthening of the infected spikes as compared with normal ones on the same plant.

The plants used in this study represent many of the progenies, and as a majority of the spikes were either all smutted or all smut-free, it was difficult to get a large number of plants that had both smutty and smut-free spikes. Often the culms bearing smutty spikes were very much shorter than normal ones and seemed stunted, but in such cases they were not measured. Only those plants that produced spikes of apparently equal vigor and of the same general height were chosen.

A total of 371 plants were measured for spike density on both normal and smutty spikes. Of these 142 were homozygous for dense spikes, 83 were heterozygous, and 146 were homozygous for lax spikes.

The increase in the length of spikelet internodes caused by the presence of smut, as shown by the mean value for the group based on the measurement of 10 rachis internodes, was found to be 74 per cent in the homozygous-dense, 53.8 per cent in the heterozygous, and 8.1 per cent in the homozygous-lax. In the homozygoys-dense, the increased length due to smut ranged from 25 to 240 per cent when the spike density of smutty heads was compared with that of normal heads from the same plant. A similar comparison within the heterozygous group showed an increased range in spike density of from 18.8 to 166.7 per cent. In both the above cases there was always an increase, 18.8 being the lowest increase in length measured. When the homozygous-lax heads were considered, 26 smutty heads were actually less dense than the normal heads of the same plant, 8 plants were the same for both normal and smutty spikes, while 112 smutty heads were from 1 to 132 per cent longer than corresponding normal heads on the same plant.

In order to test the significance of these figures from a different angle, computations were made by student's formula. The table used was prepared primarily for small numbers of comparisons so that the plants in each group were broken up into units and put through the formula, and the results were then averaged. The unit number chosen in this case was 30, which is represented by N. When N is 30 and Z is 0.8, the odds are 9,999:1 that the results are significant. The average value of Z for each group of 30 plants was found to be 2.22 for the homozygous-dense and 2.50 for the heterozygous, indicating in both cases very much greater than 10,000: 1 odds that smut has a definite lengthening effect on the shorter head types. The value for Z in the case of the homozygous-lax group was 0.2, which shows odds of 5.9 : 1, indicating that the differences are not significant in this group. The effect of smut on the length of spike would not be apparent from general observation in the case of lax spike types. The effect of smut on spike density in the three spike-density classes is shown in Table 6.

TABLE 6.—*Effect of smut on spike density*

Head type	Normal mean head length	Mean length of smutty heads	Increase in head length	Odds
	Mm.	*Mm.*	*Per cent*	
Homozygous-dense	20.4	35.5	74.0	More than 10,000 : 1.
Heterozygous	27.5	42.3	53.8	Do.
Homozygous-lax	48.4	52.3	8.1	5.9 : 1.

KERNEL COLOR

In the F_1 progeny all the kernels were red. Of the 234 F_2 progenies three plants produced white kernels; the remainder produced red. No distinction in the degree of red could be detected. In the F_3, the three plants that contained the white kernels bred true, while the 231 remaining plants showed the following segregation types: 138 plants bred true for red kernels; 23 segregated 63 red : 1 white; 45 segregated 15 red : 1 white; and 25 segregated 3 red : 1 white. A 3-factor difference was suggested as best suited to explain these results.

The probable genotypic constitutions of the parents are Kanred *AABBCC*, and Hybrid 128 × White Odessa *aabbcc*, each of the dominant factors either alone or in combination producing red kernel color. The F_2 genotypes obtained and F_3 breeding behavior for each 64 genotypes would be as follows:

Parents		*AABBCC* × *aabbcc*.	
F_2		*AaBbCc*	Segregate in F_2 63 red : 1 white.
			F_3 breeding behavior
F_2	1	*AABBCC*	True for red kernels.
	2	*AABBCc*	True for red kernels.
	2	*AABbCC*	True for red kernels.
	2	*AaBBCC*	True for red kernels.
	4	*AABbCc*	True for red kernels.
	4	*AaBBCc*	True for red kernels.
	4	*AaBbCC*	True for red kernels.
	8	*AaBbCc*	Segregate 63 red : 1 white.
	27		
	1	*AABBcc*	True for red kernels.
	2	*AABbcc*	True for red kernels.
	2	*AaBBcc*	True for red kernels.
	4	*AaBbcc*	Segregate 15 : 1 white.
	9		
	1	*AAbbCC*	True for red kernels.
	2	*AAbbCc*	True for red kernels.
	2	*AabbCC*	True for red kernels.
	4	*AabbCc*	Segregate 15 red : 1 white.
	9		
	1	*aaBBCC*	True for red kernels.
	2	*aaBBCc*	True for red kernels.
	2	*aaBbCC*	True for red kernels.
	4	*aaBbCc*	Segregate 15 red : 1 white.
	9		

1	*AAbbcc*	True for red kernels.
2	*Aabbcc*	Segregate 3 red : 1 white.
3		
1	*aaBBcc*	True for red kernels.
2	*aaBbcc*	Segregate 3 red : 1 white.
3		
1	*aabbCC*	True for red kernels.
2	*aabbCc*	Segregate 3 red : 1 white.
3		
1	*aabbcc*	True for white kernels.
64		

On a basis of three factors for red kernel color, for each 64 plants the following groups and numbers should be obtained:

True-breeding red grain	37
Segregating 63 red : 1 white	8
Segregating 15 red : 1 white	12
Segregating 3 red : 1 white	6
True-breeding white grain	1
Total	64

When this theoretical expectation was compared with the actual data, a very close fit was obtained. The group segregating 63 red : 1 white showed widest variance from the expected number, due mainly to the fact that few of the rows furnished over 40 plants, and in some cases more than half the plants of a progeny were completely smutty, thus making the chances unfavorable for the recovery of the 1 white-kerneled plant. Stewart (*12*) found that many of the errors due to lack of sufficient plants in F_3 can be overcome by growing an F_4 generation to uncover doubtful F_3 segregation.

There was little doubt as to the breeding behavior of the 15 red : 1 white and of the 3 red : 1 white groups, as from 7 to 13 plants with white kernels would be found in the 3 red : 1 white group and from 2 to 4 plants with white kernels in the 15 red : 1 white group out of a total of 40 plants used as a basis for classifying each progeny row.

The goodness of fit of the F_3 progenies on the basis of a 3-factor difference are presented in Table 7. $\chi^2 = 1.8485$ and $P = 0.7607$, which is a highly satisfactory fit.

TABLE 7.—*Closeness of fit of five groups of F_3 progenies based on a 3-factor difference in the parents, with a 37:8:12:6:1 ratio for grain color*

Group	Calculated value (C)	Observed value (O)	(O−C)	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Homozygous red grain	135.27	138	2.73	7.45	0.0551
Segregating 63 red : 1 white	29	23	−6	36	1.2414
Segregating 15 red : 1 white	44	45	1	1	.0227
Segregating 3 red : 1 white	22	25	3	9	.4091
Homozygous white grain	3.66	3	−.66	.44	.1202

$\chi^2 = 1.8485$. $P = 0.7607$.

An attempt was made by inspection to classify the grain according to the number of factors for red. No evidence was found that kernels with two or three factors for red differed in intensity of color from those having only one factor.

SUMMARY

Kanred, one of the best winter wheats in the intermountain region, was crossed with Hybrid 128×White Odessa, an introduction from the Washington experiment station. From a group of F_1 plants the most vigorous one was chosen to continue the experiment. The F_1 generation from this cross was intermediate for awns and for spike density, but the kernel color was red, resembling closely that of the Kanred parent. An F_2 family containing 234 plants was obtained, and the grain from each plant was used to seed one F_3 progeny row. The kernels were spaced approximately 3 inches apart in the row and the rows were 12 inches apart. Each row was about 12 feet long, and contained from 40 to 60 plants.

As the primary purpose in making the cross was to develop a variety of wheat resistant to bunt (*Tilletia tritici*), only one row of the Hybrid 128×White Odessa, the resistant parent, and one row of Kanred were included.

The 234 F_3 progenies were studied for the various character differences with the idea of obtaining the genetic constitution of the F_2 plants more accurately than could be determined by studying the F_2 plants themselves.

Data were collected for the following plant characters, either by observation or measurement: (1) Awn classes; (2) spike density, including the effect of bunt on the density of spike; and (3) color of kernel.

Awn classes were found to be inherited on the basis of a single-factor difference. Both parental types were recovered in the homozygous progenies of the F_3 generation. When the three genotypic F_3 progeny groups were compared to a 1:2:1 ratio, a very good fit was obtained, $P=0.8190$.

Spike density has been found to be rather stable even in years of fluctuating environment, and in this data 10 check rows of Kanred grown and measured a previous year were used for comparison.

Spike density was also found to be inherited on a single-factor basis. A very close fit of the expected 1:2:1 ratio to the data was obtained, with $P=0.5995$. Both parental types were recovered in the true-breeding F_3 progenies for the character of spike density.

The effect of bunt on spike density was indicated by an increase of from 53.8 per cent in the heterozygous progenies to 74 per cent in the homozygous-dense progenies for the length of 10 internodes. When compared to Student's formula, the results of these two spike-density types were significant by infinite odds. An increase of only 8.1 per cent was found in the case of the homozygous-lax type, a difference which was not noticeable to the eye and when measured gave odds of 5.9 : 1, which is not considered significant.

Kernel-color inheritance was found to be more complex in this cross than were the other characters studied. The data taken suggested a 3-factor difference as the explanation of the behavior of kernel color. The goodness of fit was calculated for the five groups of F_3 progenies,

based on a 3-factor difference, and it was found that $P = 0.7607$, which is a good fit.

It was impossible to determine any cumulative effect of the three factors for red kernel color. The seasonal and environmental effects caused red kernels to show as much variation in a progeny as the difference between progenies differing in the number of factors present for red color.

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